ASTRONOMY

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Phone (714) 556-2291

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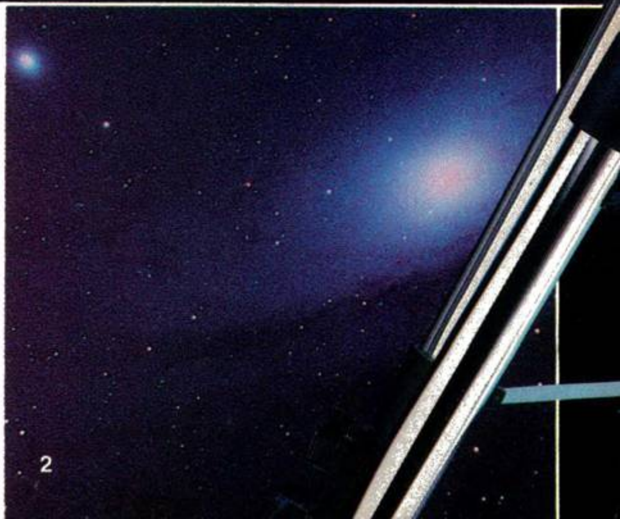
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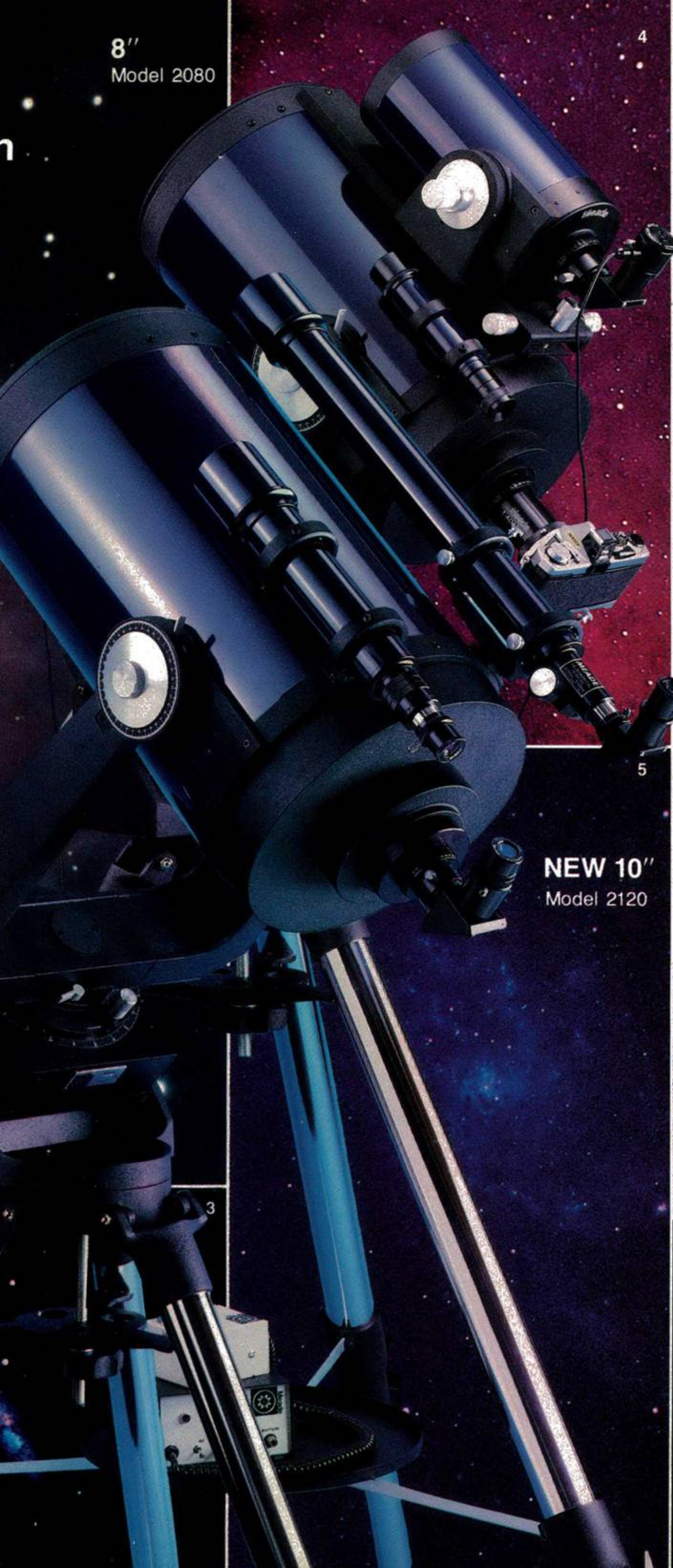

All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5, 7 — Leo Henzl; 4, 6, 8 — Emery Hildebrand;
9 — John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 60 mins. **7.** Galaxy NGC 253; 40 mins. **8.** Omega Nebula M17; 40 mins.; **9.** Moon — Clavius region; 1-sec.

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Cover: Mighty Olympus Mons dominates the landscape of Mars. This volcano is more than three times as tall as Mt. Everest and as large as the state of Arizona. Its 65 km summit caldera could hold both martian moons. (135°W, 15°N). These pages: Humans walked on the rolling plains of another world over a decade ago. Here, at the Apollo 15 landing site on the Moon, astronauts scuff the lunar regolith. The landing site is on the edge of Mare Imbrium, a great impact basin filled with solidified volcanic lava. Hadley Delta, a peak in the wall of the basin, rises in the distance. (0°W, 25°N) Photographs courtesy of NASA.

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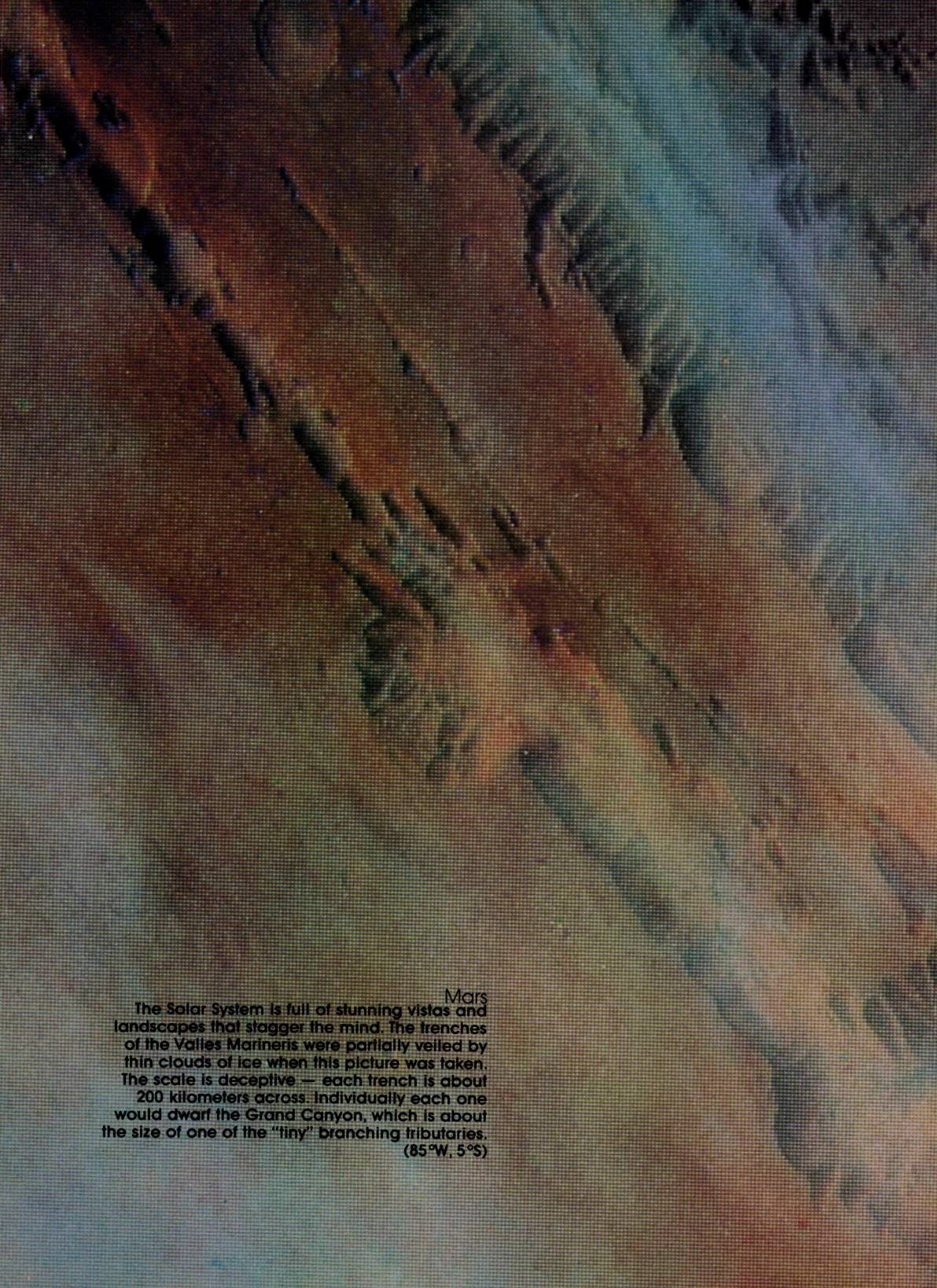
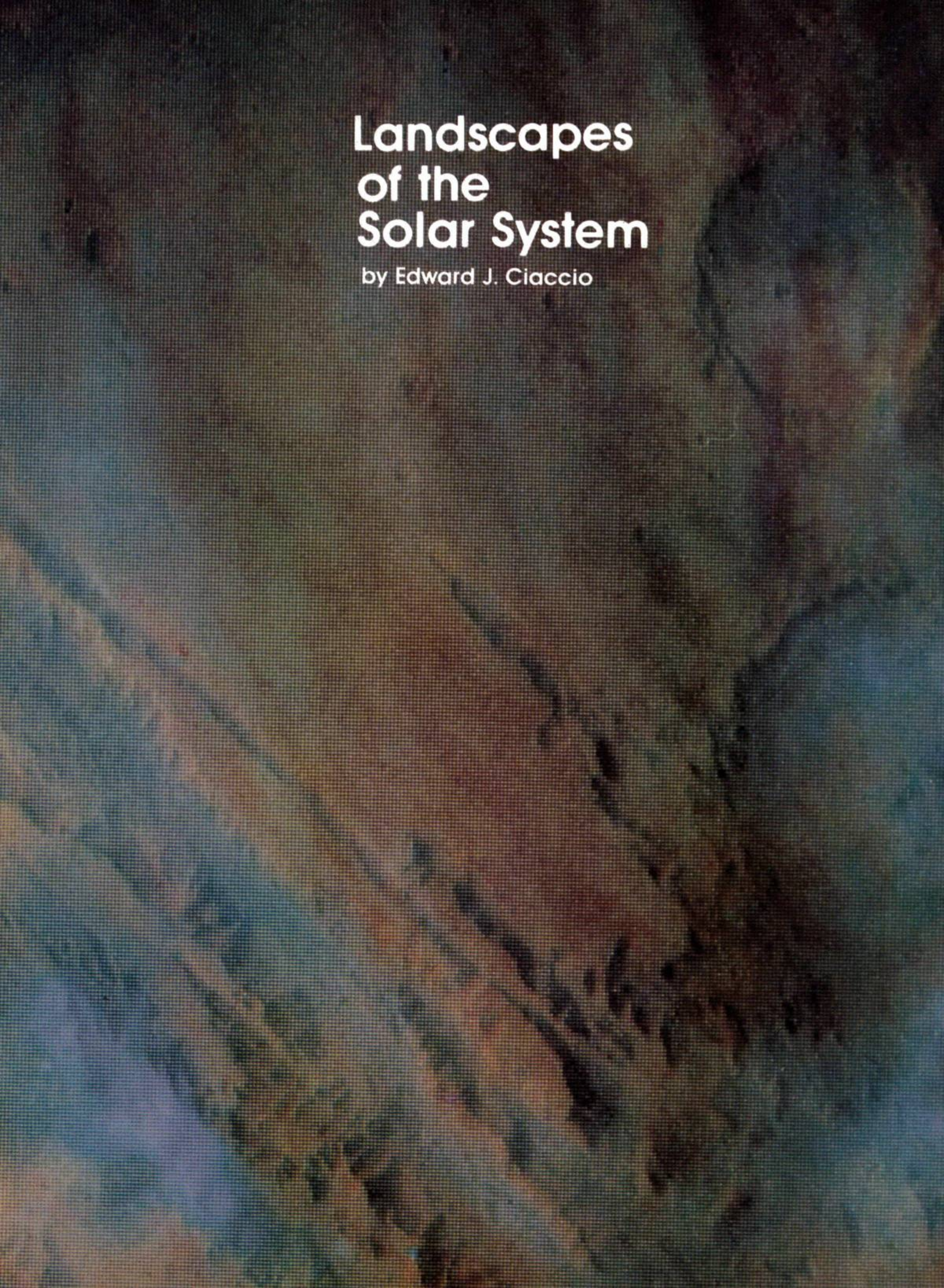


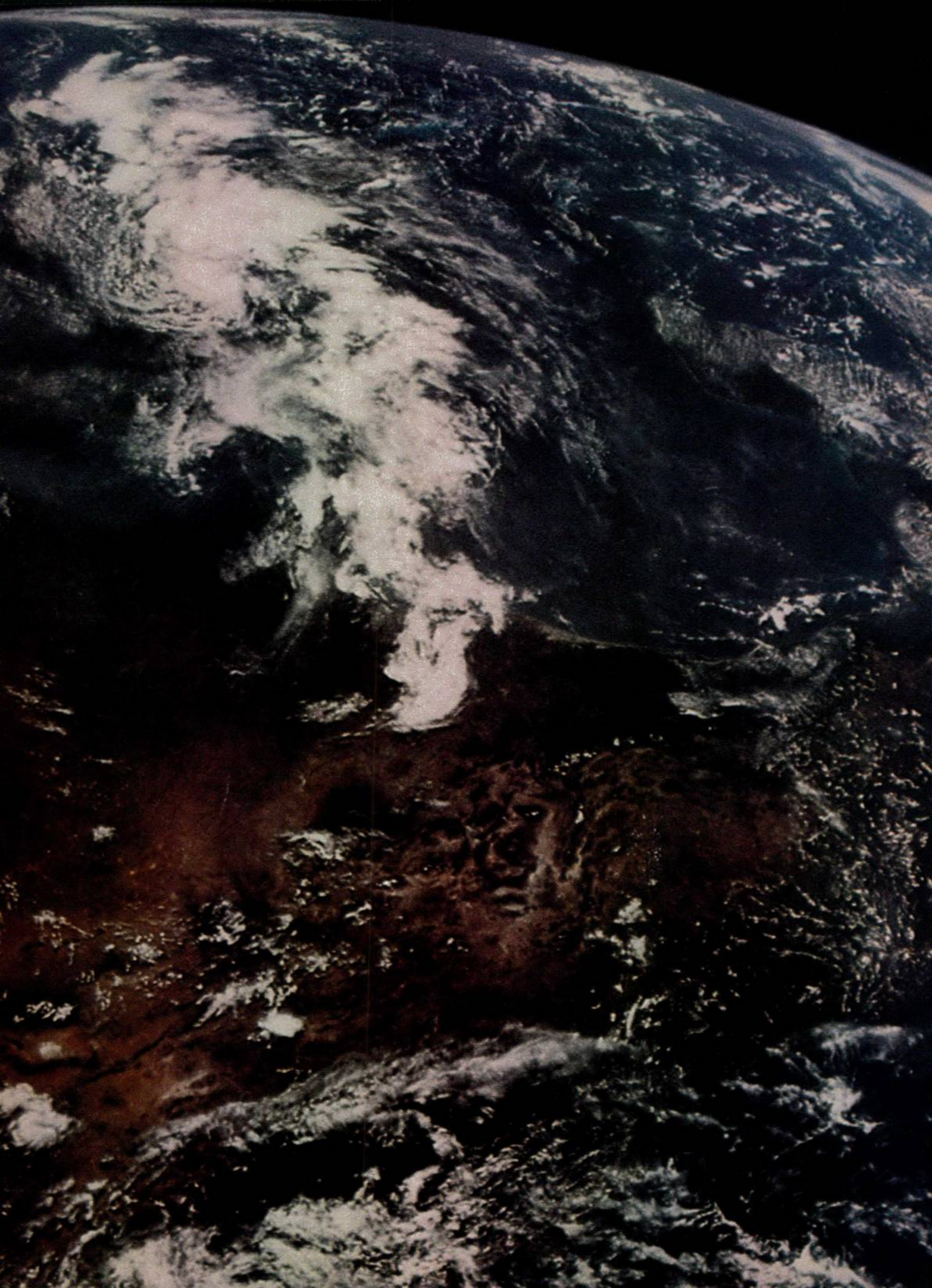
Mars

The Solar System is full of stunning vistas and landscapes that stagger the mind. The trenches of the Valles Marineris were partially veiled by thin clouds of ice when this picture was taken. The scale is deceptive — each trench is about 200 kilometers across. Individually each one would dwarf the Grand Canyon, which is about the size of one of the "tiny" branching tributaries. (85°W, 5°S)



Landscapes of the Solar System

by Edward J. Ciaccio



We live on a planet, a tiny ball of rock orbiting a star. Because humanity depends on planet Earth for everything it is and has, we owe ourselves an understanding of that planet.

In a sense, humans have been exploring Earth for thousands of years, but only in the last hundred years have we begun to comprehend the forces that drive its interior and shape its exterior. Our knowledge has given us the power both to exploit our planet and to conserve it for future generations. And only in the last two decades have our technologies and our machines been advanced enough to study other planets.

But why should we care about any of the other planets — isn't our planet Earth enough for us?

The answer, bluntly, is "no."

The growing awareness of our planet's delicate ecological balances and its limited inventory of natural resources has encouraged scientists to study dynamic Earth processes — biological, chemical, geological — and they have learned that all areas of science are related. When a scientist studies the planets, even realizing that each body looks unique, he or she examines them for the processes at work on all of them — processes that determine our own planet's past, present, and future.

But the very first step, the step that must precede more detailed understanding, is an era of discovery and exploration. We now stand somewhere near the end of that beginning, having not yet completed our initial broad survey. And our investigations are superficial, quite literally, because we have only imaged the surfaces of planets. We have not probed their interiors, nor do we know the composition of the surfaces of most. Only through the next stage of exploration, only with seismographs and direct chemical sampling, can we truly come to understand planets inside and out. Nevertheless, surfaces reveal a lot about interiors, so we can begin to reconstruct planetary pasts as we learn the processes that have shaped their landscapes.

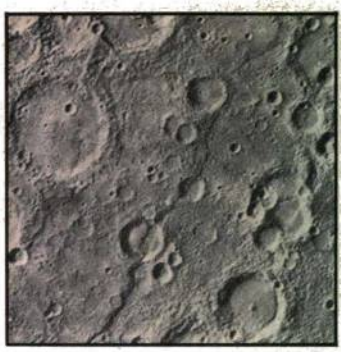
Remembering that the similarities between planetary bodies are as important as the differences, let us now plunge into a journey among the planets — a geological field trip made for us by the spacecraft of the last twenty years — and discover the landscapes of the solar system.

Mercury, closest of all the planets to the Sun, appears as a white, shimmering speck in small telescopes — even the largest Earth-based telescopes reveal only faint markings. In 1974 and 1975, the Mariner 10 spacecraft made three close flybys of this Sun-baked world. Its cameras recorded a Moon-like surface — greyish-white and mountainous, with thousands of craters of all shapes and sizes.

But on close inspection, Mercury appears not so Moon-like — and it bears a remarkable set of features unique among the surfaces we have studied in the solar system. Crisscrossing the whole planet is a series

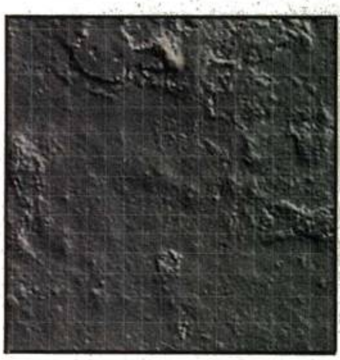
Earth

Our planet, beautiful and geologically diverse, hosts abundant life. In this image, the Yucatan Peninsula and the tip of Baja California are prominent. The brown, mountainous interiors and green coastline are easily seen through widely scattered clouds. (Apollo 11: 100°W, 20°N)



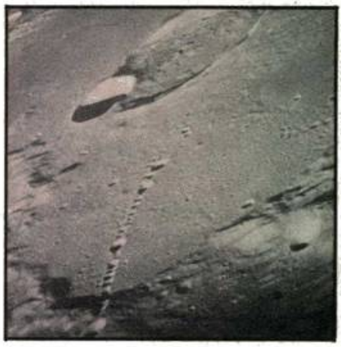
Mercury

The large, sinuous fracture running through the center of the picture is Discovery Scarp. This scarp and others like it span the mercurian globe. As Mercury cooled, its crust contracted and huge pieces began to slide across one another in an awesome geological event. Note two craters — the larger of which is 75 km in diameter — that the cliff cut and offset. (40°W, 55°S).



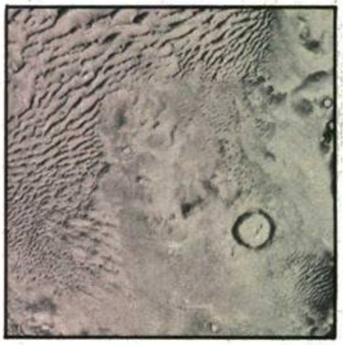
Venus

Mapped at low resolution by radar, Venus displays planet-wide plains and a few major volcanic regions: Aphrodite, middle right; Maxwell, uppper center; and Beta, middle left. Map by the U.S. Geological Survey. (80°W, 0°N)



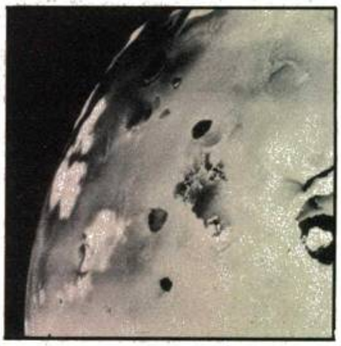
Moon

Near Davy, the large, degraded crater at upper center, is a remarkable crater chain possibly caused by a deep fracture in the Moon's surface and manifested as volcanic pits, or craters, on the surface. (Apollo 12: 5°W, 10°S).



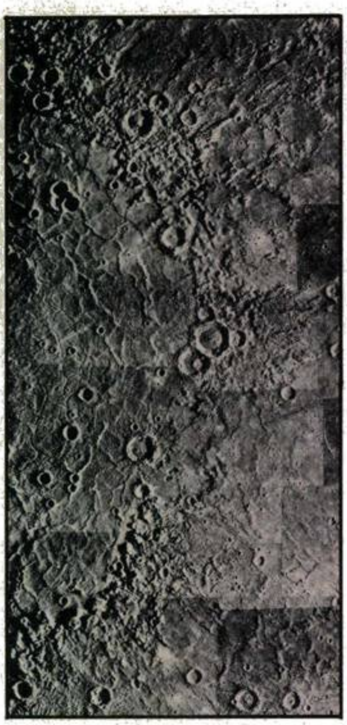
Mars

Sand dunes cluster like flocks of geese inside the 200 km diameter crater Kaiser. Each dune is about 1 kilometer wide. Small craters in this region have been covered by shifting dunes. (340°W, 45°S).



Io

Fuzzy white mountains, large black calderas, and peculiar grey patterns mark the surface of Io. The 150 kilometer-long black trench, Loki, is a source for two known volcanic plumes. Material appeared to spray from one end of the trench when the picture was taken. (350°W, 40°N)



Mercury
Concentric mountains and radial crater ejecta surround the Caloris Basin, a great "ringed basin" caused by a massive meteoritic impact. Since Caloris formed, craters have peppered it, and volcanic lavas have draped across it. Some 1300 km wide, the basin is more than one quarter the diameter of Mercury. Its center was in shadow at the time of this flyby. (185°W, 35°N)

Mercury
This planet's rugged craters are often degraded by subsequent small meteorite impacts and slumping — a phenomenon in which a slice of the crater's inner wall slides down onto its floor. Since it may happen several times, the walls can have a terraced appearance, as do those in the foreground crater. (30°W, 45°N).

Mercury
Bright material radiates from a small, recently formed crater. Rays may be covered with debris from later impacts or they may darken with time, since old craters do not have rays. (140°W, 70°S).

of lobate scarps — huge, curving cliffs. Their shadows suggest heights of about two kilometers, taller than five World Trade Center towers stacked on top of each other.

What caused them? We think that early in Mercury's history, the entire planet was molten rock and metal. The interior stayed molten for a long time — it may still be molten — while the outer portions cooled and solidified into a crust. As the interior cooled, it contracted and the crust buckled. Portions forced their way over the top of other portions — points of contact that we see as lobate scarps.

Mercury's interior melted as a result of the radioactive decay of elements present in the planet's interior. Because radioactive elements give off heat as they decay, such melting probably occurred inside all the planets and large satellites that formed with a large enough concentration of radioactive elements.

Melting is important — it causes planet-sized bodies to *differentiate*, or separate out. Dense materials sink and light materials rise, thereby forming a central planetary core of iron and nickel, a mantle composed of dense rock, and an exterior crust of light rock.

Some planets, such as the Earth, are still at least partially molten near their surfaces, so hot magmas from the interior occasionally pour onto the surface. Mercury's surface shows flat volcanic lava fields, but they are battered and ancient indicating that Mercury's interior has cooled, and has not been molten near the surface for a long time.

The most astounding mercurian landmark, the giant Caloris Basin, was partially photographed by Mariner. Produced by the impact of an object — perhaps asteroidal in size — Caloris consists of a central basin some 800 miles across surrounded by two rings of cliffs, forming a bull's-eye pattern. Great fractures cut through the center of the basin. Mercury is not the only planet that has this type of formation: others including the Moon, Mars, Ganymede, Callisto, and perhaps the Earth show signs of impacts that could have excavated Caloris-type basins.

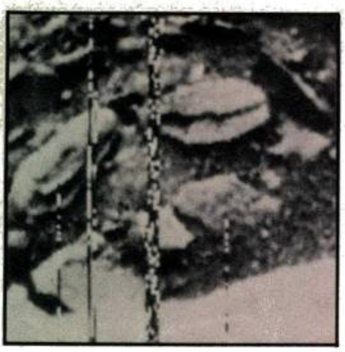
Clearly Mercury was bombarded by debris left over from the formation of the planets, as were our Moon and all the planets. But when we study the planet closely, we find two major types of surface: heavily cratered terrain, pocked with so many craters that they obliterate each other in places; and intercrater plains, flat regions of lower crater density. Thus Mercury's history cannot be simple — some process, perhaps volcanic, must have eradicated craters or smoothed the surfaces of the intercrater plains before the early solar system bombardment ended.

Our explorations of Mercury have so far been primitive — in fact, half of this planet remains utterly unknown. Because the planet's rate of rotation and orbital revolution are locked together, the same half of Mercury's surface was in sunlight during each of the brief Mariner flybys. The rest was in darkness each time Mariner flew past.

The landscapes of Venus have long eluded earthbound observers since thick clouds mask the planet's face. And its searing surface temperatures and atmospheric pressure ninety times that of Earth have rendered lifeless all visiting probes within about two hours of landing. A manned mission to the venusian surface is out of the question in the near future.

Still, four Soviet Venera landers have provided us with close-up, visible light photographs of the venusian surface. These show flat outcropppings of rock that may be volcanic. The rocks are rounded — so some force such as blowing dust has worn them

Mercury
Strindberg, about 175 km diameter, and Ahmad Baba, 115 km, contain segments of concentric ring mountains produced by the impact that formed the crater. The craters have been partially filled by volcanic flows. Chains of secondary craters produced by debris from the main impacts lead away from both large craters. (130°W, 55°N).



Venus

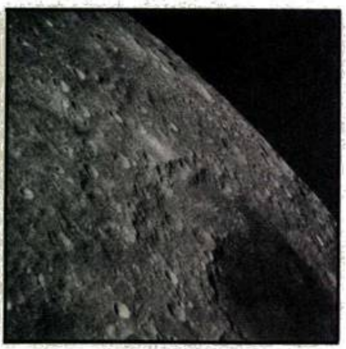
Soviet Venera 9 and 10 images taken on the surface of Venus show boulders stretching to the horizon. But the tranquil nature of the scene is deceptive — 900°F temperatures and 90 Earth-atmosphere surface pressure have destroyed all visiting American and Russian probes within hours. (Venera 9: 290°W, 30 °N).

away. (See "Revealing The Venusian Secrets," page 66.)

Can we ever learn anything about the geology of this unusual world once called the twin sister of Earth? We already have. By bouncing radar beams off the rocky surface of this hostile planet, the Pioneer Venus orbiting spacecraft made the first crude global radar "picture" of venusian topography. The information we have so far shows a vast planetwide plain cut by deep troughs. The few mountainous regions rise abruptly from the plains; one is Ishtar Terra, which contains Maxwell Montes, the highest mountain on Venus, about as tall as Mt. Everest. Radar shows that the mountainous terrain is rugged, and contains either jagged peaks or huge boulders — the radar cannot distinguish which. Faint ringed markings in the rolling plains regions suggest that at least some parts of Venus may be cratered.

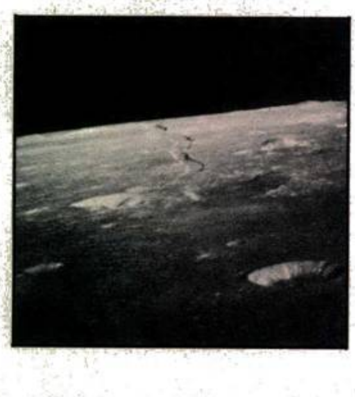
In many ways, then, Venus appears not at all earthlike. Yet it's nearly the same size, the same mass, and the same density.

From space, Earth is one of the prettiest planets. Many of us take the beauty of our world for granted, but if we lived on any other planet, we would certainly find Earth's diversity of landforms spectacular. Earth is also the most geologically interesting planet — so complex that the other members of our solar system help us understand it by their relative simplicity. A factor that distinguishes Earth, and in no small way contributes to its geological inventiveness, is water. Earth is the only planet with liquid water on its surface — an essential ingredient to geology and to the evolution and sustenance of life.



Moon

The giant crater Mare Moscoviense, on the Moon's far side, was flooded with dark volcanic lava billions of years ago. Outside the basin, parts of concentric mountain chains make the crust appear to undulate. (Apollo 13: 23°W, 25°N).



Moon

The Ariadaeus Rille is a graben, the result of tension in the lunar crust, in which a block of crust dropped. Stark mountains rise on the lunar limb. (Apollo 10: 18°E, 5°N).

Clouds cover about 50% of the Earth, but they also move rapidly allowing satellites such as NASA's Landsats to image all of our planet's surface. The quality of these pictures is so good that large landforms — mountain ranges, deserts, and plains — overflow the image frame, while roads, rivers, and fields ornament them with fine detail. Geologists use these images to map rock structures containing vital minerals, and spot areas of erosion, flooding, and pollution.

Yet something seems missing from these detailed pictures. When we gaze at the Moon with a telescope, craters dominate the landscape. The solar system is full of craters — Mercury, Mars, the jovian and saturnian moons have all been scarred by craters. On Earth most of us must travel far to see a crater. Why are there so few?

We know that Earth once sported lots of craters — as many as the other planets — but most have been erased. At the beginning of the solar system, planets and their satellites accreted from smaller bodies that had condensed from or accreted from the solar nebula. As planets formed, they removed material from the nebula, and the growth of planets and satellites slowed.

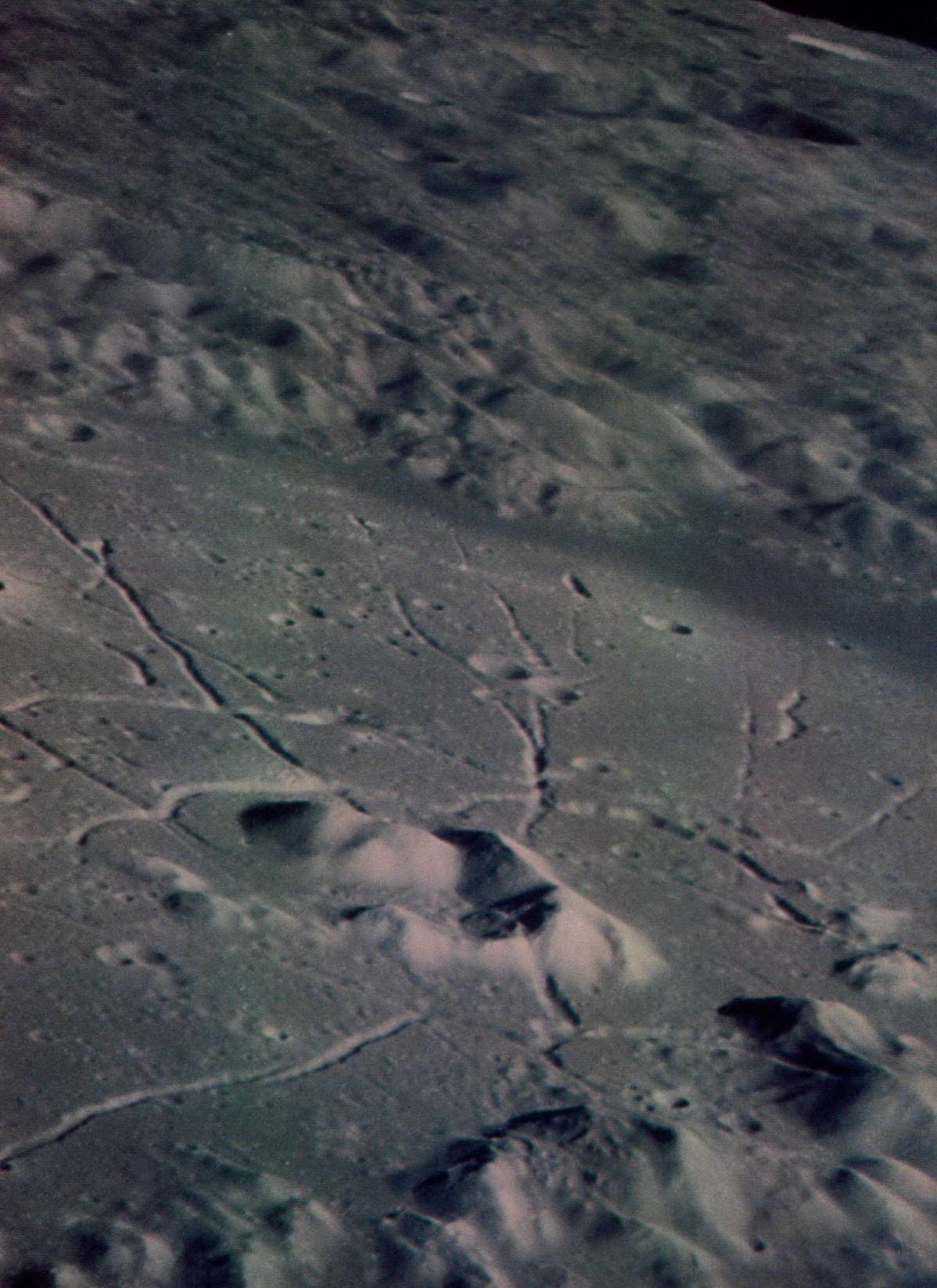
But a great deal of debris remained. Each bit — dust, rocks, boulders, asteroids — orbited the Sun until it passed near a planet, was gravitationally attracted, and impacted, forming a crater. The planets swept up most of the debris very early in the history of the solar system — a period of intense bombardment. As the planets accumulated impacts, less and less debris remained in space, and the bombardment gradually tapered off. Meteors still fall today, but most of the large objects that could collide with Earth already have.

Planets with huge numbers of craters, such as the Moon and Mercury, have what we call "old" surfaces — little changed in the 3.5 or 4 billion years since the bombardment slowed. Earth, on the other hand, has suffered much volcanic activity, and water and wind have eroded its craters — though we still see their remnants in the very oldest rocks. But another process operates on Earth, a unique process that continuously destroys and regenerates our planetary crust. It's called plate tectonics, and it works like this:

Earth's crust is broken into nine major pieces, called plates, which float on the partially molten mantle. New material for the plates rises as magma in areas called midocean ridges. When the magma solidifies, it pushes the plate away from the ridge, and broadens the ocean. Where plates come together, we see long ocean-bottom trenches where old plates plunge back down through the crust. Sometimes mountains form as plates grind into each other. And

Moon

The fractured floor of the crater Humboldt is cracked in radial and concentric patterns. Mountains rise from the center of the crater in a ring. (Apollo 15: 80°E, 25°S).



earthquakes occur where a plate forms, where it is destroyed, and at the edges where one plate slips past another plate. We see this last example at the San Andreas fault in California.

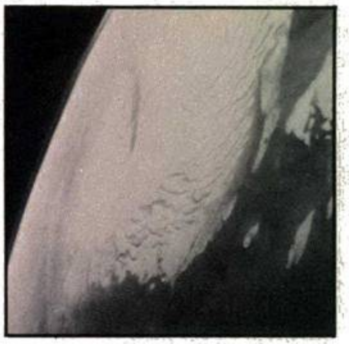
The Earth's surface, then, is dynamic. Old crust disappears; new crust appears. The surface shifts and renews itself continuously — though the motion is not readily discernible because it amounts to mere millimeters or centimeters per year. So we don't see many craters on Earth because its surface is young compared to the age of the planet, and those we do see are geologically young.

Human beings have walked on the surface of only one other planet, Earth's solitary satellite — the Moon. At one-fourth Earth's diameter, the Moon is large enough that it could be considered the junior member of a double planet system — if it were more similar to Earth. We speculated from the abundance of craters that the Moon's surface is old, and scientists confirmed this with measurements of the radioactive elements and their decay products in the Moon-rocks that the Apollo program brought to Earth.

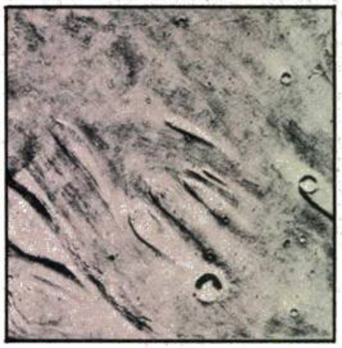
When we see pictures of the astronauts walking on the Moon, their footprints show up in a layer of dust on the lunar surface. This dust, several meters thick, is called regolith; it formed over billions of years, and about 90% of it is debris from meteoritic impacts. The remaining 10% is interplanetary dust that has fallen on the lunar surface.

The large, dark basins formed early in the Moon's history, near the end of the period of intense bombardment. Asteroid-size meteors impacted, blasting huge craters. Since the interior of the Moon was still molten, dark lava flowed from fissures until the basins filled, then overflowed, producing the flat, dark lunar *maria* we see today. We know that this happened after the period of heaviest bombardment because crater density is lower on the mare surface than it is in surrounding highland terrains.

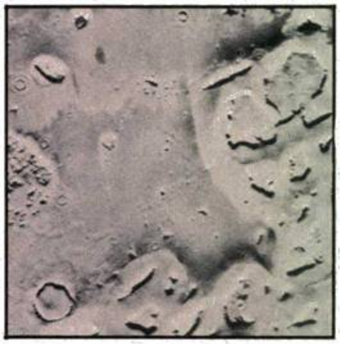
The next planet outward from the Sun is Mars. In 1964, when Mariner 4 sent back pictures showing craters on its surface, we knew little of the red planet. Since then, we have mapped its features and landed two camera-carrying probes on its surface, so our ideas about Mars have undergone a vast change. We now think of it as a world of dusty, red, boulder-strewn landscapes — a desert planet covered with volcanic rocks rich in iron oxides, or rust. We know it as a planet with a giant, possibly intermittently active volcano, Olympus Mons — three times as high as Mt. Everest. Other large volcanos cluster with Olympus Mons in a region called the Tharsis Uplift, which rises ten kilometers above the surrounding plains and stretches nearly the width of the continental United States. Our cameras have detected few craters around the volcanos in this region, indicating that the lavas that drape them are young.



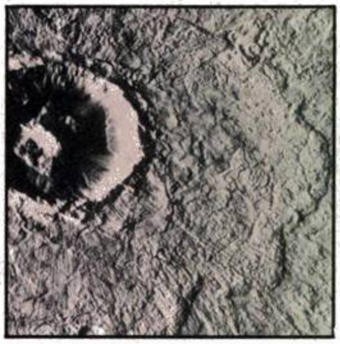
Mars
In the north polar regions, wind currents have sculpted the ice cap into a hurricane-like pattern. Layers of the ice/dust mixtures under the bright surface ice are exposed when the surface winds cut valleys into the landscape. (295°W, 85°N).



Mars
Rampart craters like Arandas feature ejecta blankets that resemble splattered mud. The odd ejecta blanket formed as the heat of impact melted the permafrost layer, creating a water and soil mush which blew out and splattered onto the surface. The floor of Arandas is about 20 km across. (15°W, 45°N).



Mars
Fretted terrain defines the boundary between the volcanic southern lowlands and the icy northern highlands. Mesas remain after the surface has been partially worn away. The small number of craters in the region, part of the Deuteronilus Mensae, suggests it is geologically very young. The largest crater is about 20 km across. (340°W, 45°N).



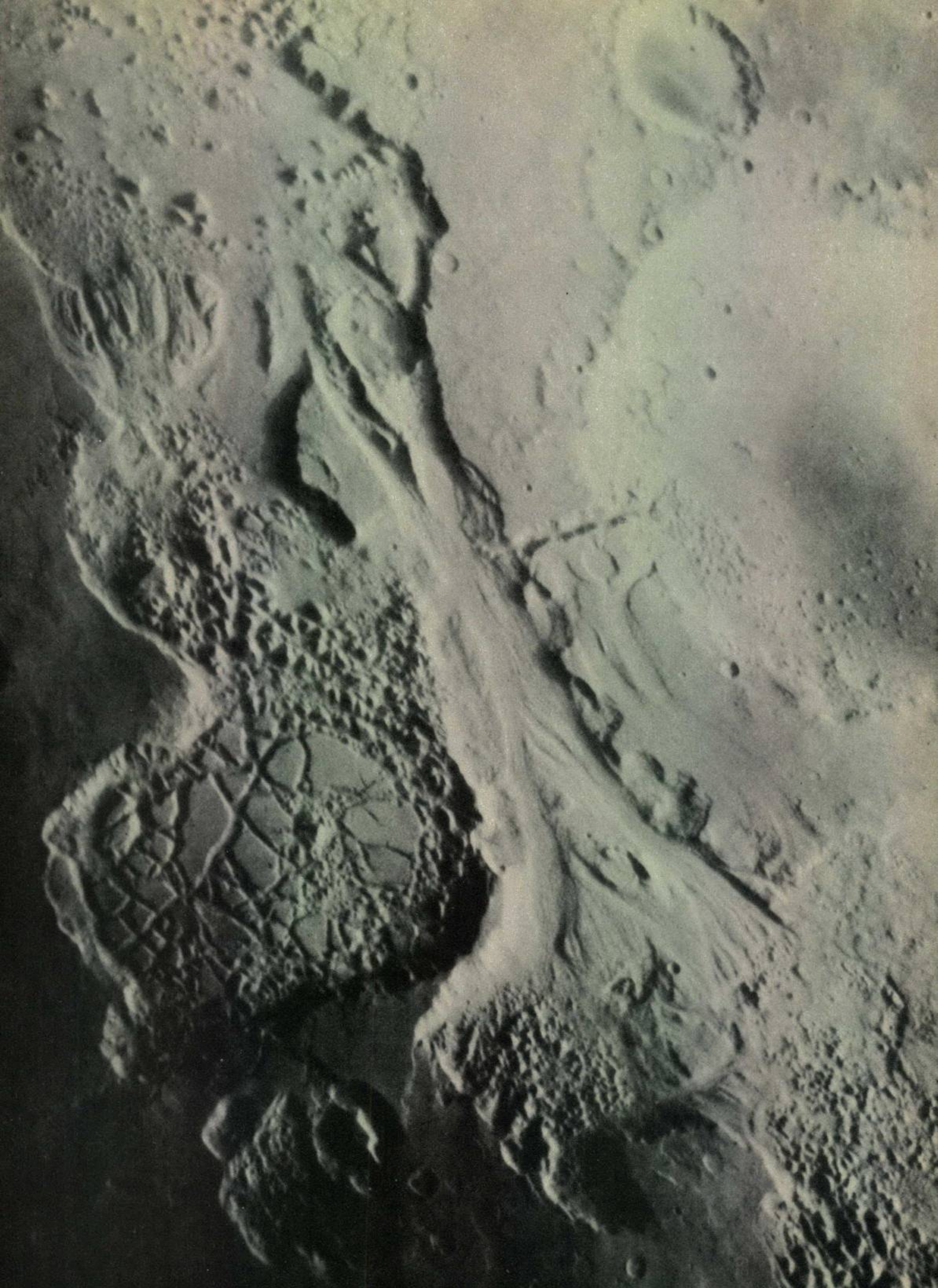
Mars
The scoured terrain near Chryse Basin was probably caused by a flood that took place billions of years ago. Water may have flowed underground during warm martian climatic periods, collecting in a depression below the martian surface until it ruptured. The largest crater is about 5 km across. (55°W, 15°N).

A great system of canyons, the Valles Marineris, spans one quarter of the martian globe. Tributaries, each the size of the Grand Canyon, branch off Valles Marineris. Material from the sides of the chasm occasionally falls to the bottom in the landslides, so this huge trench is slowly increasing in width.

Why have features of such astonishing size built up on Mars, a planet only half the size of Earth? The main reason is that Mars probably does not have plate tectonics so processes that build volcanos and canyons work undisturbed for billions of years. On Earth, a volcanic hot spot under the crust builds several volcanos in a string — such as the Hawaiian chain — rather than a single huge volcano.

But Mars is not all volcanic. Its two principal terrain types — densely cratered uplands and the sparsely cratered lowlands — are not mixed. Nearly all

Mars
The rocks in Utopia Planitia are porous, possibly indicating volcanic origin. The spacecraft landed on several rocks, so this image is tilted. (Viking Lander 2: 225.7°W, 48.0°N)



of the sparsely cratered volcanic lowlands lie in the northern hemisphere, and almost all of the heavily cratered highlands are in the southern hemisphere. In some regions, low rims of craters called "ghost craters" protrude, hinting that this region was once cratered like the southern hemisphere, but is now covered with lava.

But the most intriguing characteristic of Mars is its water. Mars apparently does not have much water, but water, in the form of ice, has played an integral role in shaping its terrain. Odd "rampart craters" are ringed with ejecta deposits that look as though mud flowed away from the crater. Since we see rampart craters in terrain that may contain a permafrost layer, we suspect that when an impact occurs there, the shock melts the underground ice. The resulting rock, water and mud could blow out of the crater, drop on to the surface with a distinctive splatter, and freeze quickly in the bitter martian cold.

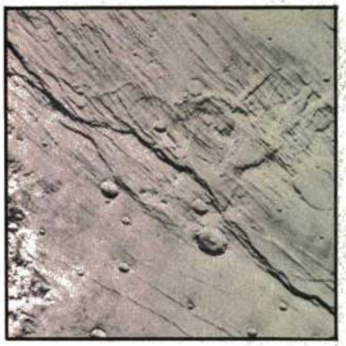
Another possible permafrost feature, *alases*, are groups of pits that lie close together and merge to form valleys in certain northern regions of Mars. To a geologist, they resemble *thermokarst* terrain seen in Siberia, landscapes formed when permafrost beneath the soil melts or sublimes away. This process, ground ice sapping, leaves an empty space under the soil, which soon caves in and forms a pit. So many of these pits have formed next to each other on Mars that they make valleys with distinctive serrated edges.

Other areas on Mars, chaotic terrains, show a landscape jumbled as though a large area of surface caved in. The surrounding terrain is scoured — as if by a sudden violent flow of water. If this is what happened, the surface of Mars preserves the traces of an event which wreaked havoc in hours but left scars that are now perhaps a billion years old.

Aeolian, or wind-driven, processes have also altered the martian landscape. In some places, the winds build dust or sand dunes many miles long and drive them across martian deserts. In other places, huge deposits of fine dust lie in the lee of craters. At the poles, dust is mixed with the water ice and dry ice of the polar caps.

Wind-driven dust serves as a clue to the past climate of Mars. In the polar ice deposits, spacecraft have imaged regions where stripes of nearly pure, white ices alternate with stripes of dusty darker ices. These layered terrains seem associated with slow changes in the martian climate. We suspect that great storms sometimes mix dust with polar ices, while at other times, perhaps in eras of milder or harsher climate, they do not.

Mars has two tiny satellites that Viking 1 and 2 Orbiters studied extensively. The larger of the two, which orbits nearer the planet, is Phobos, an irregular rock about 30 miles wide. It has one large crater, Stickney, from which curious grooves radiate. The grooves are usually widest near Stickney and typically become narrower until they end in chains of pits.



Mars

Parallel faults dominate this tortured part of Claritas Fossae. The fracturing is produced by tension introduced by the Tharsis bulge, a region of great volcanic activity. Valleys cut perpendicular to the faults in some places. This photograph shows an area about 350 km wide; the horizontal bars near the bottom of the picture are an imaging flaw. (105°W, 5°S).

Mars

Amazonis Planitia is a cratered landscape inundated by lavas from the Tharsis volcanos; only part of the wall of one crater remains. Sections of this area are young geologically — we know by the paucity of craters — suggesting recent volcanic activity. Mars may still be active in isolated regions. (170°W, 20°N).

Mars

Layered terrain near the martian north pole resembles carved wood in this closeup. The 1-kilometer-wide alternating bright ice layers and darker layers of soil and ice mixtures were deposited in earlier times and then carved by winds. Planetary scientists think changing martian climate periods determined whether ice or soil/ice was deposited. (85°N, 105°W).

Mars

Winds have worn away surface ice to reveal underlying soil layers. The layers — each about 50 meters thick — were built up during the martian past. Craters in the region are covered by wind-borne material. (245°W, 85°N)

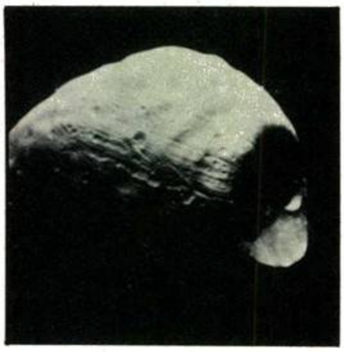
These grooves have no rims and appear unaffected by topography, which suggests they are formed from deep fractures in the body of Phobos caused by the Stickney impact. They are now partially filled in with regolith.

Deimos, somewhat smaller than Phobos, has no grooves. Its landscape is smooth, blanketed with large boulders and a regolith of fine dust — odd because the satellite has very little gravity to hold these to its surface. Both Deimos and Phobos are dark bodies possibly because of large amounts of carbon compounds in their make-up.

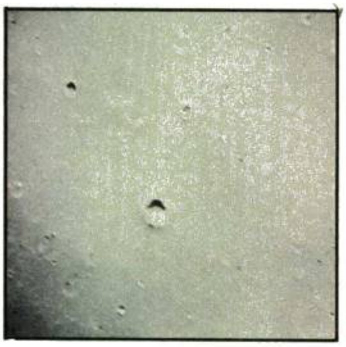
Between the inner solar system's rocky planets and the gaseous cold planets and icy moons of the outer solar system lies the asteroid belt — a

Mars

Chaotic terrain may have been the source of a great martian flood. These jumbled blocks could be the remains of crust which caved in and allowed water — under pressure and below the surface — to burst forth. Note the channels which indicate high speed water flow. Each large block, lower right, encompasses about the same area as a large city. (30°W, 5°N).



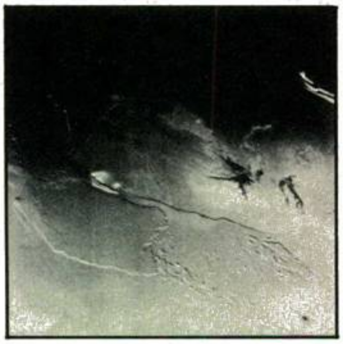
Phobos
The larger of two martian satellites, Phobos looks like a celestial olive 27 km long and 19 km wide. Striations, or grooves, radiate from the crater Stickney, which probably caused them. The largest of grooves measures 100 meters wide and 10 meters deep.



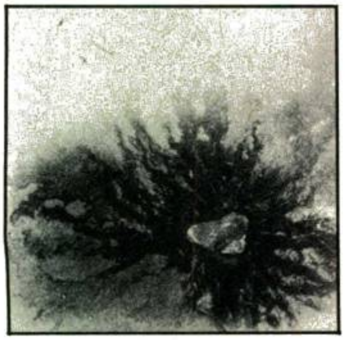
Deimos
At high resolution, house-size boulders are seen scattered between bright craters. Deimos is the smaller of the two martian satellites, measuring 16 km long and 11 km wide. The smallest features seen are approximately 10 meters in diameter.

ring of thousands of small rocky and metallic chunks. The largest is Ceres, about the size of the state of Texas. Today, planetologists think asteroids are debris from a planet that never formed, rather than the remains of a planet that broke up. Although we have never visited an asteroid, the martian moons may resemble some of them closely; they might even be captured asteroids. Scientists suspect that many of the asteroids are covered with dust layers, perhaps kilometers deep, built up from the impacts of smaller asteroids.

Because they are far less massive than other solar system bodies, asteroids have little gravity — a feature that could make them valuable to humanity. An asteroid 100 kilometers in diameter has about 1/100 of Earth's gravity at its surface; this would make mining relatively easy. A spacecraft could attach itself to the asteroid, mine and refine minerals and metals, then push off without using the enormous quantities of fuel necessary to depart from a planet with a high "gravity tax." The surface darkness of many asteroids suggests they contain carbon compounds which could possibly be made into the chemicals and fuels we will need to survive in space.



Io
Eroded layered plains near the south pole remind us of the fretted terrains on Mars. Here the surface appears eaten away by a process that may still be active. The two dark vents with flows emanating from them are about 65 km apart. (295°W, 80°S)



Io
Maasaw Patera reveals several elevation levels within the caldera. The shallower caldera has a depth of 770 meters, and is roughly 40 km in its longest dimension; the deeper crater sinks to 2180 meters. Flows of volcanic material, probably sulfurous, run in fingers down the gentle slope. We do not know whether this caldera is active. (330°W, 55°S)

The outer planets, Jupiter, Saturn, Uranus, and Neptune, are called gas giants. They are enormous compared to the rocky inner planets, massive and have deep gaseous atmospheres. There is scant evidence for a solid surface on any of them, except perhaps deep in their interiors. Yet these planets have solid satellites which approach Mercury and Mars in size, and several are larger than our Moon.

Jupiter has four extraordinary moons named the Galilean satellites, after Galileo, who saw them with his telescope in 1610. In their brief flybys, Voyagers 1 and 2 studied each body in ultraviolet light, infrared radiation, and visible light, and made images that sketch the rough outlines of a fascinating mini-solar system in orbit about Jupiter.

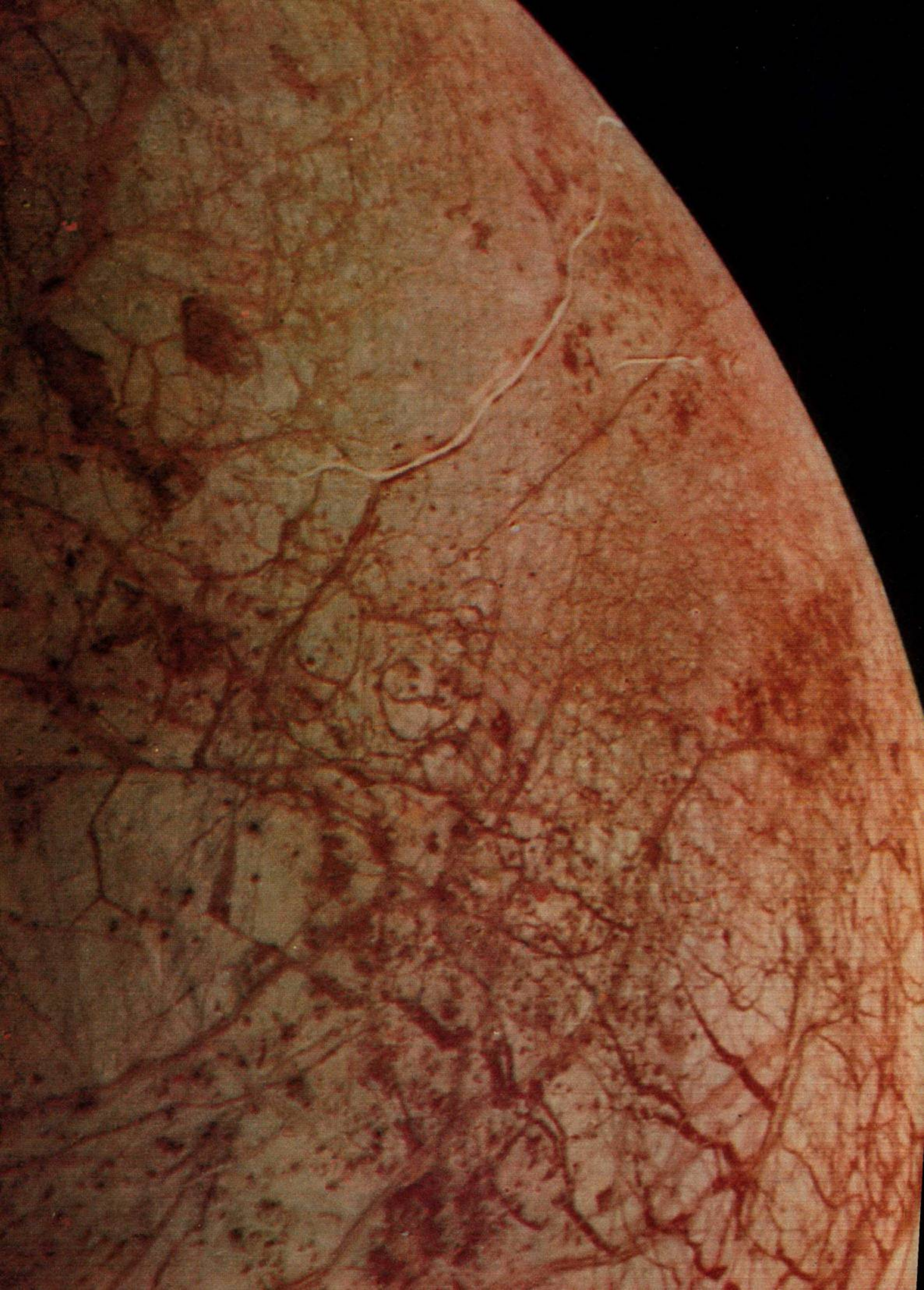
Io, the most peculiar solar system body yet discovered, is the only Galilean satellite without water-ice on its surface. Io is covered with vast quantities of liquid and solid sulfur and sulfurous compounds. Reds, oranges, yellows, whites, brown, and blacks paint the surface of this strange planet in beautiful patterns. This strange world is tidally heated by Jupiter, as the varying pull of that giant planet causes its surface to continuously pulse in and out. Craters mar Io's landscape — but they are volcanic, not impact craters. Plumes of sulfur dioxide and other sulfur compounds shoot like geysers — in excess of 100 kilometers — from some of Io's craters, changing the colors and patterns of Io as the material splashes back on the surface.

Other craters emit flows of viscous liquid sulfur. Liquid sulfur changes color at various temperatures: yellow when first melted, red at higher temperatures, and finally brown-black. The colors can be "frozen in" if the sulfur cools fast enough. Io's surface is cold enough to do this, and many of its vivid colors may be frozen sulfur flows.

Steep mountains rise abruptly at the south pole of Io. Scarps there appear worn away by gases violently expelled from cracks at their bases — gas which then freezes on contact with the surface and shows up as white deposits. Near the equator, deep black patches with sharp borders may be oceans of liquid sulfur. In the midst of all this geological activity, we see no impact craters. This suggests its surface is the youngest known on any planet in the solar system, perhaps only 100 years old.

Europa, next out from Io, probably has the smoothest surface in the solar system. Its icy crust must be very plastic or thin since it shows little

Io
Brown and white Haemus Mons, a towering 10-kilometer high mountain (lower right), is circled with a sheet of white material. Calderas, some with rings, have weird and variable colors. Creidne Patera, one such caldera, is the oval-shaped feature at center. White material appears to spray from what may be fractures in the surface.
U.S. Geological Survey Photo. (330°W, 60°S)



topographic relief: no mountains, no valleys, and only three known impact craters.

Dark lines crisscross the entire bright, yellowish-white surface. Some have a white stripe running down their centers — meaning that the dark lines may be fractures in Europa's surface and the white material is new ice that has drifted upward from the interior.

Ganymede, third of the Galilean satellites, looks superficially like the Moon, and it, too, is cratered heavily in places and lightly in others. On closer inspection, however, it reveals astounding non-lunar features.

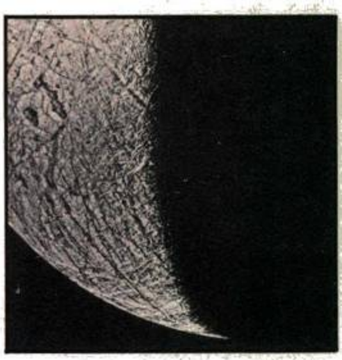
Huge dark patches spotted with pale circular markings cover portions of Ganymede. In piecing together the history of this body, we must take into account many odd features. Since Ganymede's crust is thought to be mostly water ice, dark markings are hard to explain — but they could be the result of dark interplanetary dust falling on the satellite early in its history. If that is the case, the bright patches, or *palimpsests*, formed when the darker surface was still cooling and not yet entirely solid, are scars left by large meteors that bombarded and broke through to cleaner interior ice. Water then welled up and froze as a bright marking, but because the crust was still soft, crater rims just oozed back into the satellite.

Ganymede is also grooved. Parallel sets of shallow, bright grooves wind their way across the landscape, in some places ending abruptly for no apparent reason. In other places, a light stripe cuts through a set of grooves, displacing the pieces so they do not line up. The grooves are remnants of faulting and movement of the icy crust — signs that Ganymede was active for at least part of its history.

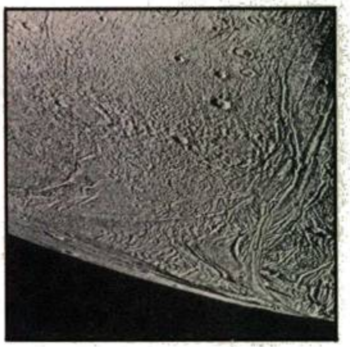
Callisto, another frozen ball of ice, is the outermost of the Galilean satellites, and is also the darkest. This moon is so dark that we think it collected large amounts of interplanetary dust on its surface during the formation of the solar system. Along with its densely cratered surface, the darkness indicates a very old surface that has not been altered or renewed since its formation.

Callisto's most striking feature is Valhalla, a large light-toned basin surrounded by about ten rings of bright material. Valhalla is the result of a catastrophic impact early in Callisto's history, a great multi-ringed scar made on a still-soft surface and frozen in for 4.5 billion years.

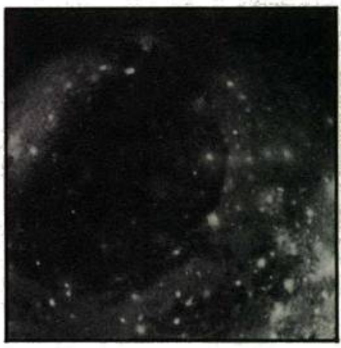
Human beings may never study these fascinating bodies firsthand. Jupiter's radiation in the region of the Galilean satellites is so intense that a human explorer would die — even robots succumb to the radiation if they remain close to Jupiter for too long. The Galileo orbiter spacecraft, scheduled for launch in 1985, will orbit Jupiter at a safe distance, dipping in quickly for high-resolution images of Callisto, Ganymede, Europa, and perhaps some of Jupiter's tiny satellites. Once the primary mission is complete, the spacecraft may be sent in to study Io until its instruments are rendered inoperable by the hostile environment.



Europa
We don't know the cause of this world's 10-kilometer-wide "ball-of-string" pattern. The terrain has little relief, and the pattern shows only under low lighting. Europa has the smoothest landscape known in the solar system. (150°W, 80°S).



Ganymede
Grooves or furrows weave along younger, sparsely cratered terrain. The grooves may have allowed new material to reach the surface, and obliterate craters. Each furrow is about 10 km wide and a few hundred meters deep. (275°W, 65°S).



Ganymede
Bright ray crater spots indicate where impacts have excavated bright water ice from below. The dark region, about two-thirds as large as the continental United States, is Galileo Regio, a fragment of old cratered terrain. The pale circles within Galileo, palimpsests, are probably the remains of craters which relaxed when the surface was warmer and softer. (140°W, 0°N)

Saturn's satellites form a mini solar system very different from the one circling Jupiter. While Saturn has one large satellite, Titan, most of its moons are small — unlike the four giants in Jupiter's cortege. The contrast between these two "model" systems suggests we should wonder how "typical" our solar system really is.

The largest saturnian satellite, orange-clouded Titan, is about the size of Mercury, but thick layers of cloud and haze completely obscure its surface. Titan's atmosphere is denser than Earth's, probably composed mostly of nitrogen with a few percent methane, and frigid at the surface. The temperature is about -300°F, near the triple point of methane — where the gas could co-exist in a solid, liquid, and gaseous state, just as ice, water and water vapor do on Earth. Titan may have a spectacular system of rainfall, glaciers, and clouds similar to Earth's except that liquid methane, not water, is the prime ingredient. Short of a lander or a manned mission, the only way we will discover what strange "geographies" lie under Titan's thick orange clouds is to send a radar imaging probe to orbit this huge moon.

Europa
Smooth and pale orange plains crisscrossed with dark lineaments about 100 km wide — perhaps fractures — describe the second jovian satellite's surface. Relief at the fractures is very slight. Europa may have a thin ice crust cracked by the intense tidal forces produced by Jupiter. Fresh ice may have recently risen to the surface along the lineament with the bright center. Note the absence of both impact and volcanic craters. (190°W, 30°S)

Another satellite, Enceladus, may contain the greatest variety of landscapes in the Saturn system. This alien world appears very bright for its small size — its surface reflects almost all of the sunlight it receives. Craters scar great tracts of its surface while other areas are nearly crater-free. Some craters appear to have uplifted, rather bowl-shaped floors. And grooved trenches have scoured great swaths of Enceladus clear of any craters — at least to the limits of Voyager 2's resolution. Long, straight valleys intersect each other at right angles and cut rectangles into the face of this satellite. The surfaces with few or no craters are probably very young, perhaps due to a recent resurfacing event — we don't know what — which obliterated all previous landforms.

Tethys is distinguished among the saturnian satellites: it has the lowest density of any planet-sized body known — just above the density of pure water ice. One titanic crater discovered by Voyager 2 gives Tethys a bull's-eye appearance. An extremely rugged, two-mile-deep chasm runs almost completely around the satellite, its sides sculpted with terraces that indicate the crust of the satellite may be layered. Though Tethys is composed almost entirely of water ice, its surface is not white or clear like other icy satellites, but a light brownish-grey due to infalling meteoritic dust.

Rhea and Dione are similar in the odd wispy markings that stripe their trailing hemispheres. These markings may be places where a volatile compound — perhaps water — has risen to the surface along fractures from deep in the satellite interiors. Once this liquid freezes, it shows as clean, bright frosty wisps.

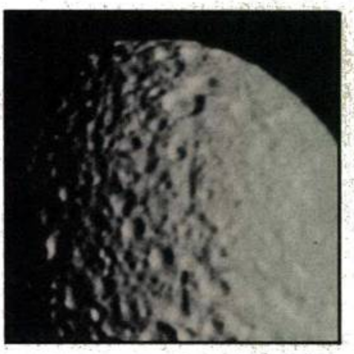
The north polar region of Rhea contains a mix of bright and dark terrains. The bright terrain has many large craters, and is thought to be older than the dark terrain, which has mostly small craters. Many rhean craters appear to be dusted with a white frost on their inner walls — clean ice exposed by slumping.

The tiny inner satellite Mimas combines a single giant crater, Herschel, with the pocked appearance of a golf ball. The giant crater has a tall peak in its center and a deep floor — quite unlike the softened crater that scars Tethys. The remaining surface is spotted with thousands of deep, bowl-shaped craters.

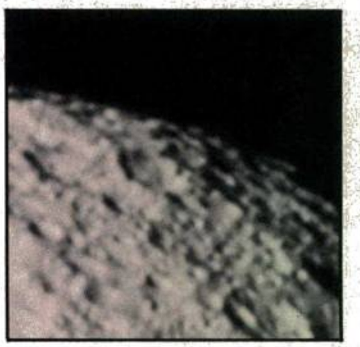
Iapetus, a large outer icy satellite, is divided by a meandering boundary into two distinct hemispheres, one very bright and the other very dark. Voyager's cameras detected no craters on the dark hemisphere — though many mark the bright hemisphere. What created the landscapes of this strange world? At present, we do not know enough about planets to understand the landscape of Iapetus.

And what about the surfaces of Uranus' and Neptune's moons, and Pluto and its satellite, Charon. Their landscapes may differ from others we have seen so far, since methane and ammonia ices are stable in the cold outer regions of the solar system. The variations we see in planet-building processes — though they produce landforms alien to these we know — could shed light on the more familiar processes. Voyager 2 will make close flybys of Uranus and Neptune, but no mission to Pluto is planned.

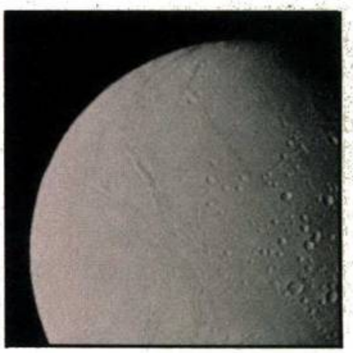
Callisto
A massive blow from a meteorite produced Valhalla, a giant impact structure with a central basin some 800 km across. The crater and the ring-mountains that encircle it probably formed billions of years ago. The dark brown-purple surface of this satellite may be an accumulation of dark meteoritic material. The center of Valhalla is located at 55°W, 10°N.



Mimas
A small body cratered to saturation, Saturn's satellite Mimas has preserved the scars of its formation in its cold, rigid ices. Yet even Mimas shows signs of geological activity; several troughs break the pattern of craters.



Tethys
The battered landscape of this icy world looks lunar, but it is not. The surface of Tethys is made of highly reflective ice, while Earth's Moon is made of dark grey rocks and lava. Tethys is only one-third the diameter of the Moon.



Enceladus
"Fabulous" is the only way to describe this tiny but geologically active saturnian satellite. What process has eradicated craters over large tracts of its surface? Why is the surface grooved and cut by faults? Processes occuring on remote mini-planets may help us understand our own planet.

As we continue to probe the planets, countless new and startling discoveries await us. Much of the value of exploration lies in finding what we did not expect to find. Yet these discoveries show us more than the marvelous beauty of our celestial neighbors; they help us learn more about our own home — the blue-white gem we call Earth.

Photographs accompanying this article are courtesy of the National Aeronautics and Space Administration (NASA), unless otherwise noted. Figures in parentheses following each caption are the planetocentric longitude and latitude of the center of each photograph; these will aid you if you wish to locate features on a map.

Edward J. Ciaccio is a graduate student in the Department of Planetary Science at the Lunar and Planetary Laboratory of the University of Arizona in Tucson. His research work involves synthesizing chemical compounds that might be present on the surface of Io. He would like to say "thank you" to John Spencer for reviewing the manuscript, and to Concetta Ciaccio for her proofreading and typing.

ASTRONOMY FORUM

Congressional Hearings on Space

In February of this year, the Reagan Administration sent its Fiscal Year 1983 budget proposal to Congress. It was a disaster for planetary exploration. The administration canceled the Venus Orbiting Imaging Radar (VOIR) mission, expressed its desire to end the operation of Pioneers 10, 11, and Pioneer Venus, and slashed the funds needed to analyze the data collected by planetary spacecraft.

The first Congressional body to consider the space science budget was the House subcommittee on Space Science and Applications. Out of its hearings has come some of the sharpest criticism of the Reagan version of planetary exploration.

The questions that followed the NASA presentation showed the administration had put little thought into writing the budget. As part of the budget proposal, for example, NASA will launch the Galileo Jupiter mission using a two stage IUS booster instead of the more powerful Centaur booster it had planned to use. Congressman Harold Hollenbeck (R-N.J.) questioned Andrew Stofan, Deputy Associate Administrator for Space Sciences and Applications, about that decision. Keep in mind that this isn't Stofan's budget; it's the President's. Stofan has worked hard to keep the planetary program going.

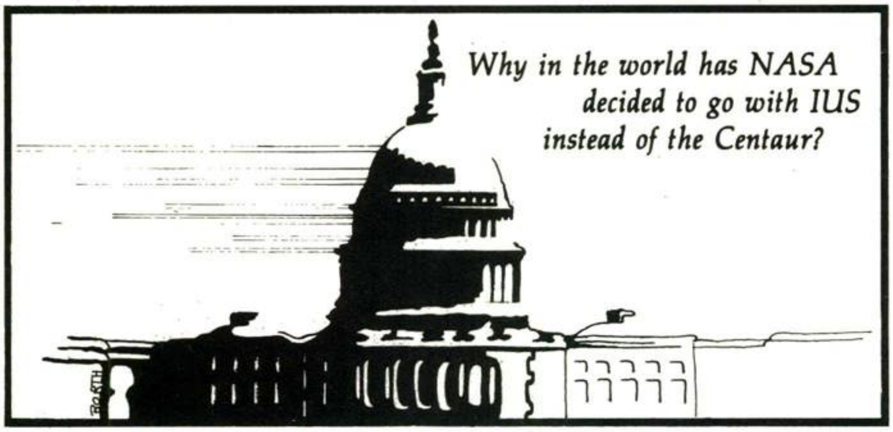
HOLLENBECK: NASA's administrator indicated two weeks ago that there would be less information returned by Galileo if it was launched on the IUS instead of the Centaur. Could you comment on that?

STOFAN: That adds approximately 30 months to the mission, so Galileo will arrive at Jupiter in late '89. It is a 30-month delay in returning the science. Galileo will also arrive at Jupiter with less fuel. Because of this, it will be guaranteed just six flights past the large moons instead of the original 11.

HOLLENBECK: The IUS does not have the potential for planetary missions the Centaur can provide?

STOFAN: That is a fair assessment.

At this point Congressman Bill Nelson (D-Fla.) took up the questioning.



NELSON: Has NASA ever flown an IUS?

STOFAN: Not to date.

NELSON: The Centaur has flown lots of times?

STOFAN: The existing Centaur has flown 60 missions. There would have to be modifications to it for the Galileo mission.

NELSON: What has been the success rate of Centaur?

STOFAN: Greater than 90%.

NELSON: Why in the world has NASA decided to go with IUS instead of the Centaur?

STOFAN: [no response]

NELSON: The Centaur could get Galileo there by '87 instead of '89. You said the IUS has never been tested, and that Centaur has a 90% success rate in 60 missions, and that the Centaur's lift capability is much greater. Why would we go with the IUS instead of Centaur?

STOFAN: Two reasons. One is the risk of modifying the Centaur in time for the '85 launch. I don't think the risk is very high, but there was some small risk.

The other consideration was a near-term budgetary problem. If you look at the two alternatives in the long run, their costs will be very close. If you look at the short-term, the Centaur budget requirements were much greater than the IUS.

NELSON: In the long term, the cost to the U.S. government is going to be about the same, and in performance the Centaur is far superior to IUS. Therefore, the only reason NASA has selected the IUS is that in the short term it is less expensive than the Centaur, right?

STOFAN: That, and the worry about meeting the launch date on time with the Centaur.

Three days later, the same subcommittee heard from three planetary scientists and from three executives of aerospace companies.

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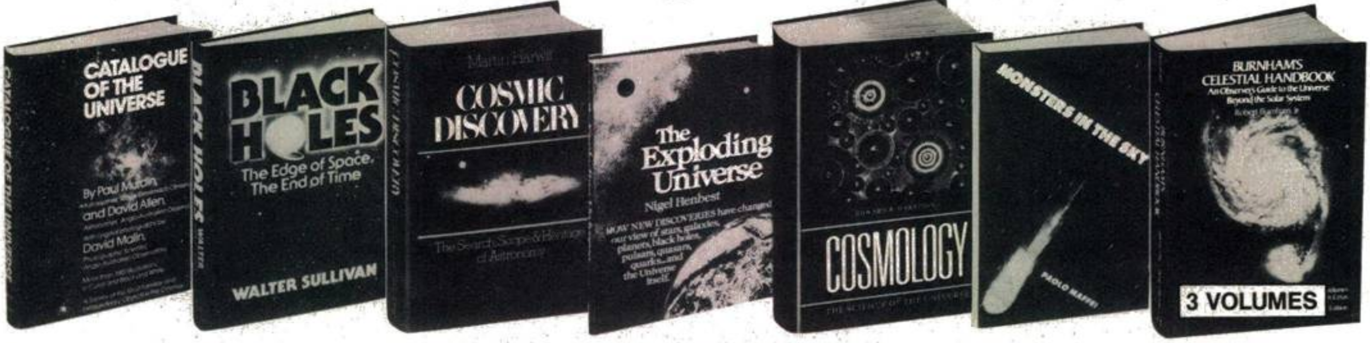

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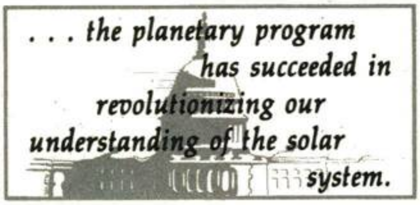
David Morrison, Professor of Astronomy at the University of Hawaii, focused on the planetary program's current plight:

It is with amazement that I find myself here today, facing the collapse of this program for planetary exploration. There have been no launches of planetary spacecraft since 1977, and no new starts since FY78.

Only a single planetary launch is anticipated during the 1980s. Year after year, the necessary support base has eroded as planetary exploration has received a steadily shrinking fraction of the NASA budget. Now, with the proposed FY83 budget, this process of slow fiscal strangulation is being replaced by a more rapid phase-out, with termination of work on the Venus Orbiting Imaging Radar, the abandonment of several operating spacecraft, and slashes in the support level for planetary research to half its FY81 value.



> ***. . . the planetary program has succeeded in revolutionizing our understanding of the solar system.***

NASA is abandoning any pretext of a balanced space program. It is turning away from exploration, apparently prepared to resign from its position of leadership in this field. The proposed budget is a disaster for planetary science and exploration, and I am here to argue the necessity of restoring this program to FY81 levels if the U.S. is to maintain the capability to explore the solar system through the decade of the 1980s.

The planetary program of which we speak has, for the past 20 years, pursued broad objectives of science and exploration. Its long-term goals are to gain an understanding of the origin and evolution of the planetary system, to obtain perspective about the Earth as a planet in order to understand the processes that control our environment, and to gain insight into the origin and history of life. In addition, it has been recognized that detailed study of the Moon and asteroids is a prerequisite to the possible utilization by future generations of extraterrestrial resources.

Through vigorous pursuit of a balanced program of flight missions and supporting research and analysis, the planetary program has succeeded in revolutionizing our understanding of the solar system. U.S. spacecraft have visited some 40 new worlds, an effort that climaxed in the second half of the 1970s with the Viking landings on Mars, the Pioneer probes of the atmosphere of Venus, and the Voyager expeditions to the jovian and saturnian systems. As the decade of the 1980s began, we were at the peak of our capability, with a technological and scientific base for deep space missions that had taken 20 years to build.

Now we are rapidly losing that unique capability. NASA officials may speak of "mothballing facilities" or "deferring programs," but you can't mothball or defer the people whose special dedication and knowledge make this capability a reality. Already they are leaving, changing careers, or moving to the growing Western European space program. Implementation of the proposed FY83 budget will, I am afraid, cripple our capabilities to the point where years of effort and tens of millions of federal dollars will be required to restore what we are throwing away by shortsighted and arbitrary cuts that even NASA officials acknowledge are temporary in nature.

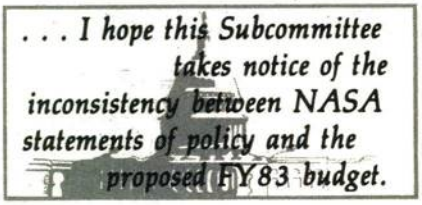
I do not need to point out to this Subcommittee that these programs have been extremely popular as well as successful. Public interest in planetary exploration has never been higher. During the past two years there have been six cover stories dealing with space in *Time* and *Newsweek*; three of these dealt with the Space Shuttle, but the other three concerned planetary exploration. Millions of Americans watched Carl Sagan's highly successful television series, *Cosmos*, and millions more shared in the Voyager Saturn encounters. The Planetary Society, formed a little more than a year ago to support the planetary program, now has more than 100,000 members, making it the fastest growing membership organization of any kind in America.

In general, planetary exploration has high visibility at home and abroad, as a symbol of United States science and technology. I have found great surprise among the public and press when I have pointed out that all this has been achieved by a program that represents only 3% of the NASA budget. Surely this has been not only one of the most popular and successful, but also one of the most cost-effective programs of the federal government.

Until now, it has been NASA policy to maintain a balance among the space science disciplines, pursuing a broad range of initiatives in space astrophysics, solar and plasma physics, and the life sciences as well as planetary. The National Academy of Sciences and other science advisory groups have supported this approach. All of these areas of science are being greatly advanced by access to space, and each has achieved significant breakthroughs as a result of the NASA program.

As the NASA space science budget has declined under the fiscal pressures of the past few years, efforts were made to maintain this balance of programs. Now, in the proposed FY83 budget, we see a welcome increase in the space science budget, yet at the same time effort to maintain the balance has been abandoned. Apparently someone has made a decision to phase out planetary exploration, although I know of no NASA policy statement to that effect. Nor has such a course been advocated by any science advisory panel either inside or outside of NASA.

In testimony you have received the past two weeks from Mr. Beggs [NASA's administrator] and Mr. Stofan, lip service is still paid to the goal of a vigorous planetary program, and, as you know, it is NASA policy to continue work on the Galileo Jupiter Probe and Orbiter. At the same time, the rest of the planetary program has been gutted. Something is seriously wrong here, and I hope this Subcommittee takes notice of the inconsistency between NASA statements of policy and the proposed FY83 budget.



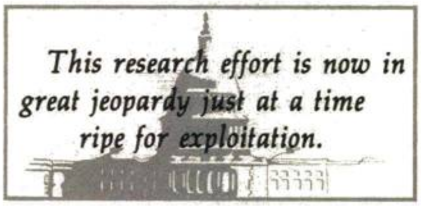
> ***. . . I hope this Subcommittee takes notice of the inconsistency between NASA statements of policy and the proposed FY83 budget.***

Verner Suomi, professor of meteorology at the Univerity of Wisconsin — Madison, focused on the promise planetary exploration has for understanding the Earth's climate and how budget cuts threaten that promise:

We already have a good theory for the Earth's weather behavior, particularly for large scale storms, and our daily forecasts make good use of this theory. Climate variations are also very important in our complex society, maybe even more important than the weather. Despite their importance, our ability to predict climate is not good . . . .

Must we explore the planets to

better understand the Earth's climate? The answer to that question must be "no," because, as a colleague has stated, "If we lived in a solar system without any other planets but with an Earth just like our own, we'd have to try to understand the world's climate anyway." However, will the opportunity to study the atmospheres of other planets aid us in solving our climate problems? The answer is just as surely, "yes."



> *This research effort is now in great jeopardy just at a time ripe for exploitation.*

The variations in climate so important to us are much more subtle than the changes we experience from summer to winter. We get into difficulty when a little winter-like weather gets into our summer and vice versa. A slightly early thaw can mean flooding; a slightly early frost can mean substantial crop losses. These subtle changes are the Earth's response to various perturbations in the amount of direct solar energy, change in volcanic activity, increase in carbon dioxide and other boundary conditions which affect the Earth's gain of heat from the Sun, the loss of the Earth's heat to space and the distribution of what remains over the Earth.

These *small* changes on Earth resemble the *large* changes that we obtain in going from planet to planet. Mars, for instance, can have "instant climatic change" in one of the giant dust storms. The solar energy that reaches Jupiter and Saturn is very feeble compared to that received on Earth, yet these planets have enormous wind systems with hundreds of cyclones and anti-cyclones. The winds near the equator on Saturn roar along at over a thousand miles an hour, yet it receives only 1/100 of the Sun's energy we do. What's the reason? We don't know. Venus has a steady wind system in its ever present cloud layers much like the intermittent ones we have in our tropics . . . .

In recent years we have seen beautiful images of the outer planets, their cloud systems, and we now have good data on their atmosphere's composition and structure and wind systems as well. In addition, thanks to previous support by Congress and over a hundred other countries of the world, we have the best description ever of the Earth's atmosphere as a complete global whole . . . . Indeed, we are in a position to make a "research killing" if we exploit the rich data supply collected from both the Earth and the planets. The measurements that have been made are a precious commodity, but they are not the end product. Understanding, and its ultimate benefits to mankind, will come only after study and thought. We should do our best to make use of the data we already have. This analysis process is sufficiently underway to suggest that the potential return is indeed very great. This research effort is now in great jeopardy just at a time when exploitation is ripe.

Even a cursory view of the Planetary Program in the NASA budget shows Research and Data Analysis, the items which should be *increased* now that we have such a large valuable body of data, instead actually are being sharply *decreased*, by nearly 50% in just two years. To prevent this decrease deserves a high priority in your deliberations.

Albert D. Wheelon, a senior vice president and group president at

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Despite its past successes, the planetary program is in serious trouble. The trends and recent events are all negative. There were 38 lunar and planetary launches in the 60s, 14 in the 70s, and, with the cancellation of VOIR, one approved mission for the 80s. In five years, there has been no new program successfully initiated. When adjusted for inflation, the proposed FY83 planetary budget of $155 million, is one-fifth the planetary program expenditures of ten years ago and two-thirds the expenditures of five years ago.

Accompanying the funding decline are a vacillation and uncertainty of purpose that are seriously undermining the program. The problem has been compounded by unwise decisions made in regard to launch vehicles required for planetary missions.

> ***The problem has been compounded by unwise decisions made in regard to launch vehicles required for planetary missions.***

The Galileo program is a notable example. Originally scheduled for launch in 1982, Galileo will now be launched in 1985. The upper stage planned for Galileo has changed three times in the last year. In 1980, NASA decided to separate the Probe and Orbiter and launch them separately on the IUS. A simple Probe Carrier was thus needed for the Probe mission. In December 1980, NASA announced that Hughes had won a competition to build the Probe Carrier. In January 1981, NASA announced it would recombine the mission and cancel the Probe Carrier procurement. The costs saved by canceling the Probe Carrier would help underwrite the development of a new Centaur stage for the Shuttle. However, the Centaur plans were recently canceled — Galileo will now be launched on an IUS two-stage. The mission is to be combined — it will just take 2½ years longer to get to Jupiter.

There are other examples similar to the Galileo history. International Solar Polar Mission was canceled soon after full-scale development was initiated. Solar Electric Propulsion has been started and stopped several times over the last few years. After years of study and debate, we have passed up the unique opportunity of exploring Comet Halley in 1985.

The most recent example of vacillation is the VOIR program. The program was eliminated from the FY83 budget after several years of program definition and competition, after substantial [Hughes] company resource investment by JPL and four major aerospace companies, after VOIR was established in the FY82 budget, after teams had been formed, after all plans were laid out and full-scale development was about to start.

This vacillation is wasteful. It undermines the basic science objectives of the program. For example, the FY83 budget proposes terminating the scientifically prolific Pioneer Venus orbit data taking mission to save $7.5 million while adding $20 million to Galileo to accommodate programmatic changes. Several productive planetary missions could be created from the waste that has resulted from the recent erratic course NASA has followed in regard to planetary spacecraft and their associated launch vehicles.

This approach to the planetary program has been inefficient, discouraging to the participants, and threatening to the future. This problem — the lack of a steady course — is fundamental and transcends the FY83 budget problem. If the situation continues, the institutions supporting the planetary program will dissolve. For Hughes, the loss of business would be inconsequential. We would focus on Department of Defense and commercial programs. If necessary, we could reconstitute our planetary spacecraft capability later on by drawing upon our Defense Department and communication satellite capabilities. However, once dismantled, the NASA, JPL, and science community institutions would be difficult to reconstruct. Considering the value we have received from the planetary program and its relatively small cost, I don't believe we should dismantle our program. Rather, I think we should be establishing a policy that gives the program a direction consistent with today's budget limitations. . . .

We believe a healthy and vigorous planetary program can be comfortably included in NASA's current budget allocations. We believe that there are many missions with modest cost that can sustain the science, adventure and prestige benefits that this country has enjoyed in the past. To illustrate my point, let me cite a few examples of missions we have studied over the last several years:

— A Delta — an inexpensive booster — launched Halley intercept mission with cometary imaging and other science. Total mission cost: $100 million.

— A series of atmospheric probes to the outer planet bodies with atmospheres: Saturn, Titan, Uranus, Neptune, Total mission cost: less than $50 million per year.

> ***. . . once dismantled, the NASA, JPL, and science community institutions would be difficult to reconstruct.***

— A Mars orbiter focused on understanding the Mars climate and evolution of water on that planet. Total mission cost: $100 million.

— A simplified Venus mapping mission with 1-kilometer resolution. Total mission cost: $250 million.

I suggest that the Administration and Congress define an acceptable level of spending for the planetary program and allow NASA and science community to implement a series of modest missions. A planetary program budget of $150 to $200 million per year — about 4% of NASA's overall budget — would be adequate to sustain the type of low cost missions I've described. It would be consistent with the current environment of budgetary restraint. It would allow us to continue our productive planetary program. The science community would be able to continue the exploration of the solar system. The nation could continue to enjoy the adventure of exploration. Having received clear direction, NASA would be able to proceed in an efficient manner to fulfill its mission. Industry would benefit from a more stable program and could contribute its technology developed for the Department of Defense and commercial market. Eventually, if budget permits, more ambitious missions could be superimposed upon this solid base of planetary exploration.

A few weeks after the hearings, the subcommittee voted to increase the planetary budget by $23 million, a little less than half the amount that was cut. It was one battle partially won. Of the four congressional committees that have a say in the space science budget, however, this is the friendliest. The future of planetary exploration isn't assured.

— Van R. Kane

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eye on the sky

moon overshadows planet parade

by Fred Schaaf

the wanderers

During July a series of conjunctions in the southwest summer sky follows a sequence of planetary oppositions. But special celestial events equal or even surpass the beauty of these planetary activities.

The most fascinating happening this month is a total eclipse of the **Moon**; full details appear in Gazer's Gazette. Totality will last an amazing 106 minutes — almost the maximum duration possible. This is also eastern North America's first good look at lunar totality since 1975; the western states saw the eclipsed Moon in September 1979.

Since the Moon passes through the center of the Earth's shadow, the lunar face will be dark at mid-totality. We'll have to wait and see if clouds of volcanic ash will have an additional darkening effect. Let's hope for clear skies over the entire viewing area for this evening of the long eclipse.

Don't let the attraction of an eclipsed Moon blind you to this month's other superb events. You can see the three bright outer planets contracted into a span of only 15° — their smallest angular spread until the very end of the century.

The magnificent arrangement of **Mars, Saturn** and **Jupiter** will also include first magnitude Spica. The most active component in the changing configuration will be **Mars**. Its first conjunction is on the evening of the 9th, when it is just 3° 8′ south of **Saturn** while both are nearly at quadrature, 90° from the Sun.

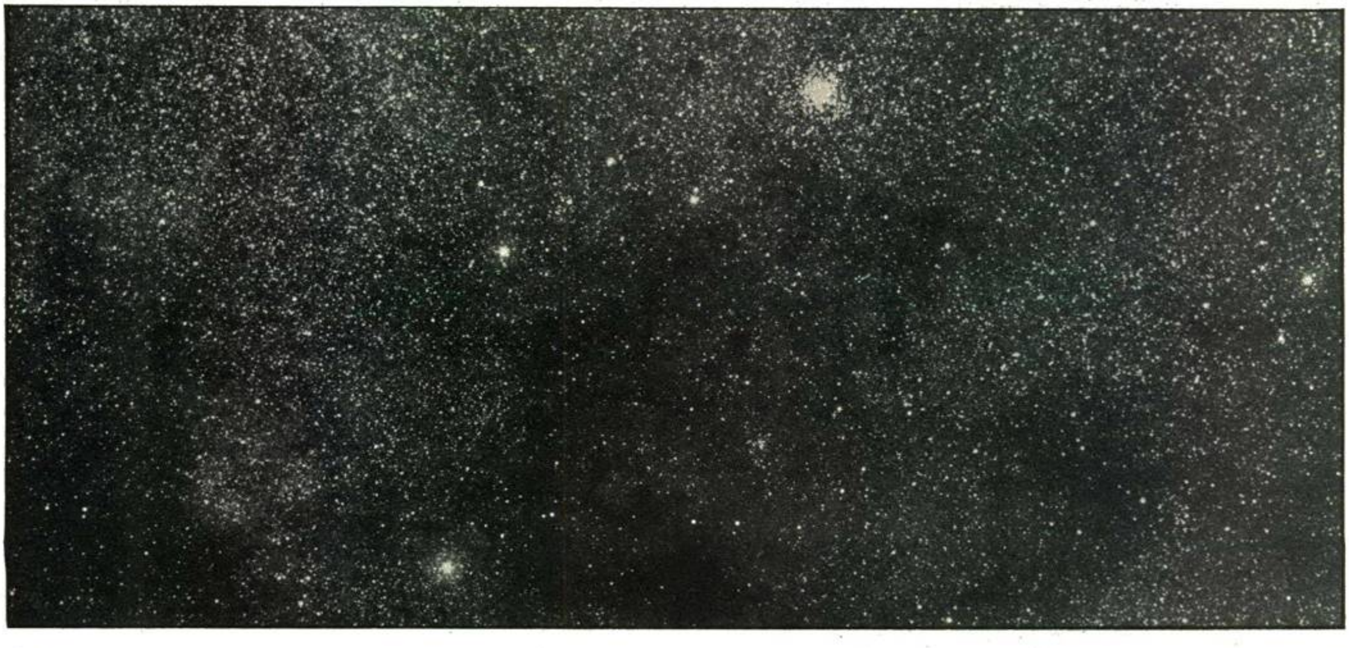
About a week after the Mars-Saturn conjunction, the Red Planet approaches Spica and settles in the gap between that star and Saturn, completing a compact line of splendor. Compare the color and brightness of the three on these nights: Mars is the brightest and somewhat ruddy in color, Saturn is gold, and Spica is blue-white. Both the ringed planet and the star are first magnitude objects this July.

On the 21st, Mars passes just 1° 33′ north of Spica. Mars does not approach closer to Spica again until June 29, 2046!

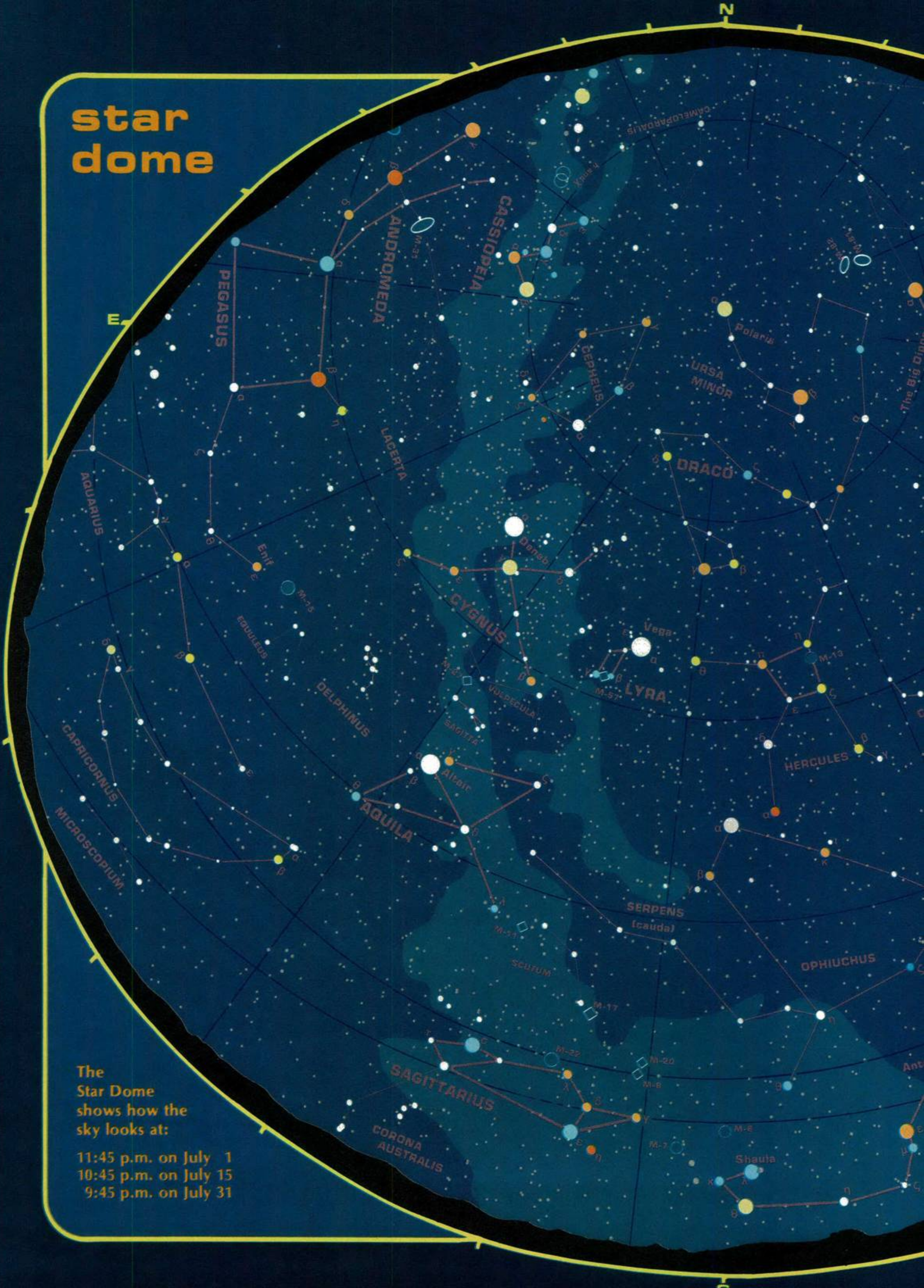
The tight configuration of Mars, Saturn, and Spica is not alone in this part of the sky. Mighty **Jupiter** shines at magnitude –1.7 just to their east.

All month long, watch the rapid motion and dimming of Mars and try to answer these questions: When will Mars catch up to Jupiter? How close will it pass? How bright will it be? You can see that the conjunction must occur sometime next month since

This snowy scene (right) reminds us of Orion's wintery domain. Bob Garrison made this 17-second exposure with a 50mm lens and Ektachrome 200. Below is the open cluster M-11, high in the southwest on July evenings. Rick Dilsizian photographed it with an 8-inch Schmidt camera and a 7-minute exposure.

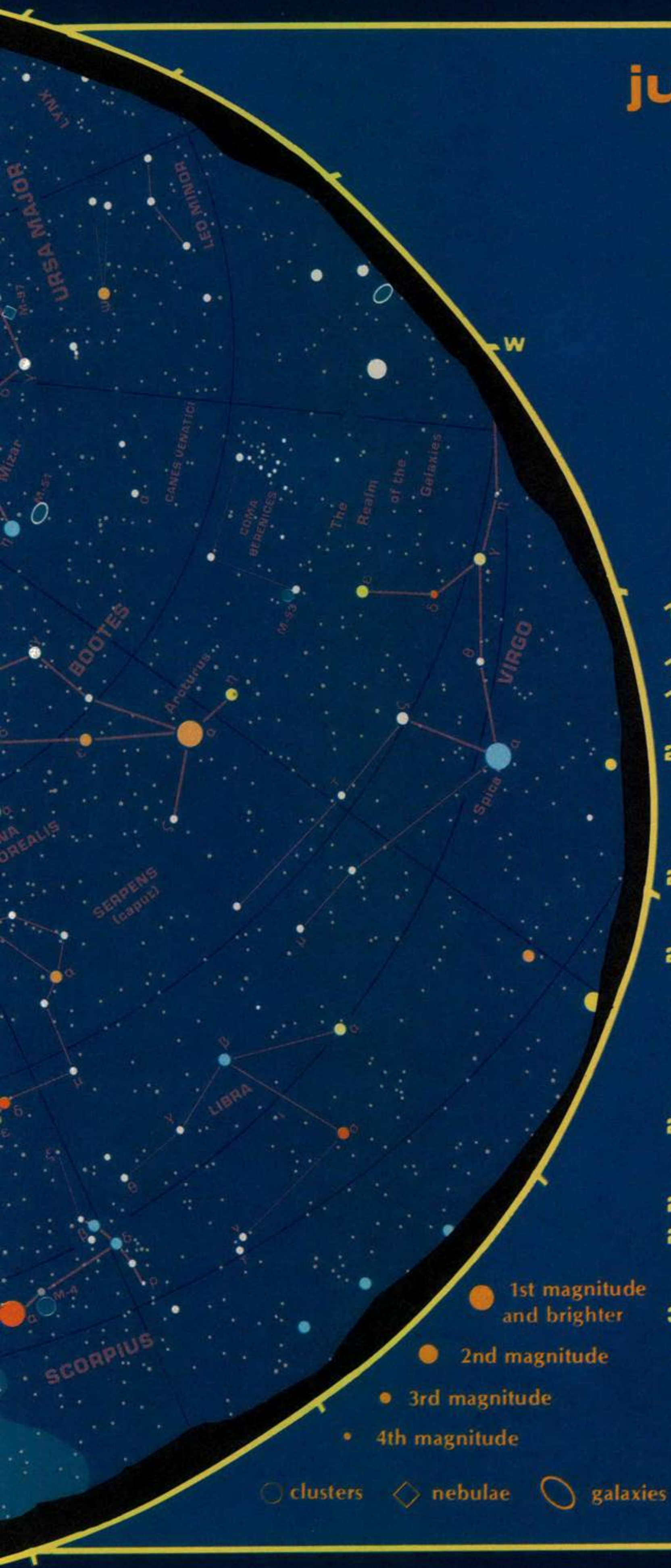


star dome


N
E
CAMELOPARDALIS
CASSIOPEIA
ANDROMEDA
M-31
PEGASUS
CEPHEUS
URSA MINOR
Polaris
The Big Dipper
M-81
M-82
DRACO
LACERTA
AQUARIUS
Enif
M-15
EQUULEUS
DELPHINUS
CYGNUS
Deneb
Vega
LYRA
M-57
M-27
VULPECULA
SAGITTA
M-13
HERCULES
CAPRICORNUS
MICROSCOPIUM
Altair
AQUILA
SERPENS
(cauda)
M-11
SCUTUM
OPHIUCHUS
M-17
M-22
M-20
M-8
SAGITTARIUS
M-6
M-7
CORONA AUSTRALIS
Shaula
Ant

The Star Dome shows how the sky looks at:

11:45 p.m. on July 1
10:45 p.m. on July 15
9:45 p.m. on July 31


LYNX
URSA MAJOR
LEO MINOR
M-97
Mizar
M-51
CANES VENATICI
COMA BERENICES
The Realm of the Galaxies
M-3
W
BOOTES
Arcturus
VIRGO
Spica
CORONA BOREALIS
SERPENS (caput)
LIBRA
M-4
SCORPIUS
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

july sky almanac

4th	In the predawn sky, Venus lies near the star Aldebaran in Taurus. Earth is at aphelion: 94.5 million miles. The Moon is at apogee late tonight: 252,377 miles.
6th	Full Moon occurs at 3:32 a.m. EDT, and you'll see a total lunar eclipse (see Gazer's Gazette).
9th	Tonight, Mars will be about to overtake Saturn, 3° south of it. Mars is the brighter of the two and has an orangish tint.
13th	Last Quarter Moon is at 11:47 p.m. EDT.
17th	Mercury is at perihelion.
19th	The Moon is at perigee this evening: 222,549 miles.
20th	New Moon occurs at 2:57 p.m. EDT. A partial eclipse of the Sun is visible from the arctic regions and northwestern Europe.
21st	Tonight Mars lies about a degree-and-a-half north of the star Spica in Virgo.
25th	Mercury reaches superior conjunction with the Sun today and switches from the morning to the evening sky. But it won't be visible for another month, and even then it will be difficult to find in the Sun's glare.
26th	Tonight the Moon is near Mars, between Saturn and Jupiter.
27th	Full Moon is at 2:22 p.m. EDT.
29th	Peak activity for the Delta Aquarid meteor shower occurs during the predawn hours.
30th	The Capricornid meteor shower peaks today.

The compact constellation Lyra lies almost at the zenith during mid-summer evenings. It contains many telescopic wonders, including a double double star, the Ring Nebula, and Vega, the brightest star in the sky. Jack Newton used a 135mm lens at f/3.5 and a 5-minute exposure on ASA 400.

Mars will have already crossed the line between Spica and Jupiter as July comes to a close.

The three planets and Spica are strung together with a crescent Moon on July 25, 26, and 27. After moonset on those nights, you can also enjoy the activity of several meteor showers. The most numerous meteors are likely to be the **Capricornids** and the **Delta Aquarids**. Both showers stream out of the south in the post-midnight hours.

Finally, if you find yourself up very late on these short summer nights, you will be treated to a morning twilight view of **Venus**. The –3.3 magnitude planet is not well-placed these days, but it will pass 14′, 14′ and 5′ of arc north of three third magnitude stars in Gemini on July 23, July 24-25 and August 4. Watch for these close approaches in the pre-dawn sky. During this period the shrouded planet's elongation lessens from 27° to 24°. On July 4 Venus is a full 4° north of Aldebaran.

You can catch a glimpse of the other inner planet, **Mercury**, much lower in the northeast before dawn in the early part of July. But it soon sets as it moves toward superior conjunction with the Sun on the 25th.

the starry sky

A dragon, a scorpion, and two head-to-head giants compete with roaming thunderstorms for the prime position in July evening skies.

High in the north, the head of the ancient dragon **Draco** is marked by the **Lozenge**, a figure of stars that serves as a fine scale for estimating magnitudes, or testing the quality of your skies. It is formed by stars of 2nd, 3rd, 4th, and 5th magnitude. The brightest of these is **Eltanin**, the next brightest is Rastaban, then Grumium, and Kuma — the last is a pair separated by slightly more than one minute of arc.

The two components of **Kuma** (Nu [ν] Draconis) are virtually identical in brightness, and white; you can split them with a pair of binoculars on a tripod. And Patrick Moore claims that Kuma can be split with the naked eye. Why not test your vision?

One of the legendary giants in the sky is **Hercules**. Few constellations cover a larger area of the heavens than the strongman does. Besides its great globular cluster, Hercules also contains a notable single star, Alpha Herculis, or **Rasalgethi**. The name translates to "head of the kneeler," and marks that position in the constellation. Rasalgethi is an irregular variable with a brightness that fluctuates between magnitude 3.1 and 3.9 in a 90 day period. Telescopic observers know it as a dramatic double star, and its red giant component is one of the largest stars known.

Adjacent to "the head of the kneeler" is "the head of the serpent-charmer," Rasalhague. The snake charmer is **Ophiuchus**, a constellation in which solar system bodies spend more time than they do in nearby zodiacal Scorpius. A look at a star map reveals that Ophiuchus is right side up, but since Rasalgethi is in southernmost Hercules, the strongman appears upside down as seen from North America. This strange positioning has come about as a result of precession, the millennia-slow movement of the Earth's axis. The ancient inventors of Hercules and Ophiuchus saw these constellations sloping down the north and south skies, respectively.

Rasalhague also serves as a corner point for an alternate version of the **Summer Triangle**. The true Summer Triangle lies east of Hercules and is formed by three first magnitude stars: **Vega** in Lyra the lyre, **Deneb** in Cygnus the swan, and **Altair** in Aquila the eagle. Rasalhague is not much farther from Vega than Deneb is and forms a similar triangle. Rasalhague is bright at magnitude 2.1, but still almost a magnitude fainter than Deneb.

We cannot pass on south from Hercules and Ophiuchus without first looking east to admire the now-high sapphire of summer, **Vega**. As darkness grows deep on July evenings, compare this star with **Arcturus**, at a similar altitude in the west. Which of these stars is brighter? Don't fault yourself if you can't answer from naked-eye observation — it was a long time before careful measurements showed that Arcturus is imperceptibly brighter. Notice the beautiful contrast of Vega's blue to Arcturus' orange.

For another star of prominent and different color, look down in the south. You will find ruddy **Antares**, the heart of **Scorpius** the scorpion. The name means "rival of Mars" and the rivalry is one of color. Antares is usually about magnitude 0.9, about half a magnitude dimmer than Mars currently is, but by the time it approaches and then passes Antares in October, the Red Planet will be comparable in brightness.

Antares is a red giant surpassed in size and range of variability, and perhaps redness, only by Betelgeuse. These two stars are almost the same distance from us.

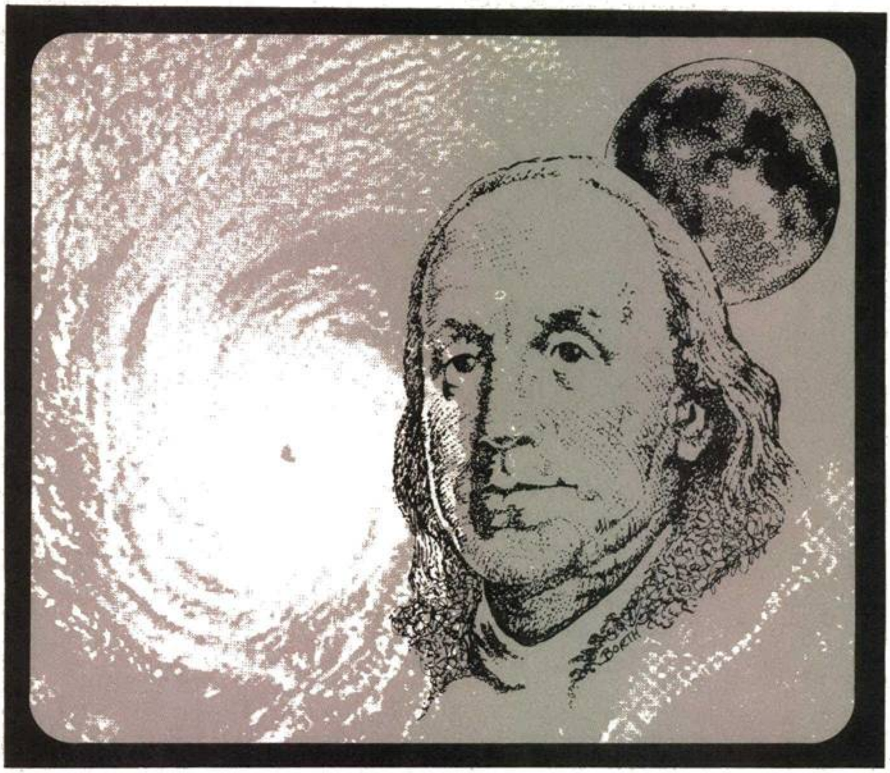
Scorpius is an awesome constellation, but unfortunately very low for the northern U.S. and especially for Canadian viewers. Its brilliant length currently spans the gap between **Uranus** — located in the prominent vertical line of the head — and **Neptune**, in the midst of Milky Way a number of degrees above the stinger.

The most famous star in the head of Scorpius is **Beta** (β) **Scorpii**, or Graffias. This multiple star system is near the ecliptic and in 1971, the giant Jupiter occulted its components. On the same occasion, several teams of observers were in just the right places to see an even rarer event: the occultation of the 4.9 magnitude C component by the moon Io.

skylore

Historical events often meld into legends as the years pass. Such is the case with some of the adventures that involve total lunar eclipses.

On Columbus's fourth voyage to the New World, the admiral found himself and his men stranded on the north coast of Jamaica. Columbus sent out a party to sail for help from the Spanish colony on Hispaniola, but during the long wait the natives grew increasingly unfriendly and at last refused to bring the sailors any more provisions.



Luckily, Columbus knew from a copy of Regiomontanus's *Ephemerides* that a total eclipse of the Moon would occur on February 29, 1504. He told the natives he was God's servant and was displeased at them for refusing him aid, and that he would cause the Moon to become "inflamed with wrath." The eclipse began just as the Moon peeked over the horizon and the red color — the inflammation — amazed the natives, for it seemed impossible to them that any man could know in advance of this terrifying event — unless he was informed by God.

The natives appealed to Columbus, who of course relented just as totality ended. The crafty admiral had not only solved his plight — the natives were ever after eager to please — but he had also used the opportunity to determine the longitude of Jamaica by measuring the local time at which the eclipse occurred!

Another total eclipse of the Moon played a role in the greatest disaster in the history of ancient Athens — the defeat of the Athenian forces that attacked Syracuse under the command of Demosthenes and Nicias.

Thucydides tells how the attack on a night of bright moonlight ended in bloody confusion, with men unable to tell friend from enemy in the fighting. Demosthenes counseled the next day that the Athenians should withdraw, but Nicias resisted. When reinforcements arrived for the Syracusans, Nicias relented, and on the night of August 27, 413 B.C., the fleet of Athens secretly prepared to leave. But at the very moment of departure, an eclipse of the Moon began.

According to Thucydides, most of the Athenians were "deeply impressed by this occurrence" and "now urged that the generals wait." Unfortunately, Nicias was "somewhat overaddicted to divination and practices of that kind" and refused even to consider departure until they had waited the thrice nine days prescribed by the soothsayers.

What followed was one of the grimmest defeats in history, as the Athenians were cut off from retreat. Nicias and Demosthenes were captured and put to death, and about 7,000 Athenians were enslaved in quarries outside Syracuse. The conditions of their imprisonment were so horrible that most died within eight months.

Our final story shows how even an eclipse cloud-out can be turned into a marvelous discovery — if you are as shrewd as Ben Franklin. Old Ben was looking forward to observing a total eclipse of the Moon, but was disappointed by bad weather of a most peculiar kind. Franklin learned that observers in Massachusetts had been able to see the big astronomical event and he became curious about the nature of the storm that had ruined his plans to observe in Philadelphia but had reached Boston somewhat later.

By a careful study Franklin figured out — from the changes in wind direction — that the storm rotated counterclockwise as it moved up the coast. The storm was a hurricane, and Franklin, more than a century ahead of his time, deduced that a low pressure system had a counterclockwise flow. He had made the best out of a situation that would disappoint any astronomical observer.

ASTRONOMY
IN FOCUS

Mood Pieces

Sir / In early January this year, I saw the Sun bracketed by two exquisite parhelia or "sun dogs." I had seen this only once before and I was intrigued by it.

Just a few weeks later, the February issue of ASTRONOMY arrived with John Mood's "Watch the Skies." My enjoyment of that excellent article was compounded with a feeling of shared experience with the author. The article also brought to mind the other atmospheric events I have had the pleasure to observe, including rings around both Sun and Moon, rainbows and even a "snowbow." If only for that, I would have cause to thank Dr. Mood.

Then, on the morning of February 8, I left for work at 6:00 a.m. It was one of those mornings of this past brutal winter when low-temperature records were shattered across the country. The cold was obvious as soon as I stepped from the door, and a high haze overhead confirmed the forecast of yet another snowstorm.

Northwestern New Jersey is blessed with hilly and wooded but uncluttered horizons, and as I sat in the passsenger seat of my friend's pick-up traveling east, I watched the beacon of Venus cutting through haze and a salmon-pink glow of air pollution as dawn began. Aircraft contrails arrowed down beyond the silhouetted hills toward New York City eighty miles, and a world, away.

I have a healthy prejudice against the Full Moon, since it has ruined many a rare free night with my telescope, but I appreciated its presence that morning. Even through the haze it was bright enough to cast shadows, and the frozen snow on the ground reflected its light back into the air and created an eerie frigid aura over the landscape. I turned to glance through the pick-up's rear window and was greeted by one of the most beautiful sights I have ever seen.

Morning haze had erased most of the detail from the face of the Moon, leaving a brilliant disk in the western sky. I first noticed one and then another parhelia (parlunia? moon dog?) glowing ghostly at the 22° position. These ethereal natural specters were bright enough to be unmistakable once I noticed them. They were accompanied by a dimmer and ragged 22° halo that could only be seen well be shading out the Moon with a gloved hand. The combination of the sky's apparitions with the frozen landscape and the bare, spooky trees added up to a sight which will stay in my memory for many winters to come.

Russ Hinkel, Jr.
Phillipsburg, NJ

Sir / I found John Mood's "Watch the Skies" in the February 1982 ASTRONOMY quite interesting. On February 27, I observed a peculiar apparition involving a jet trail and the Sun. From where I was standing, the shadow of the trail extended in front of the jet and could actually be seen moving ahead as the jet proceeded. At one point this streak extended to the horizon.

Apparently conditions were just right for a "watcher of the skies," because I also saw a 22° halo around the Sun.

John Mihm
Wilton, IA

Sir / I wish to express my appreciation to the ASTRONOMY staff for producing such fascinating articles and photography. Before I subscribed, I acquired by chance a stack of ASTRONOMYs from a friend. Being an avid reader, it wasn't long before I wanted more.

I have always held an interest in science. When I was around 10, I was fascinated with Alan Shepard's sub-orbital flight and dreamed of being an astronaut. Time has passed, and I'm now riding the rails as a brakeman on the Burlington Northern. Sometimes it brings me down — the mundaneness of life. But when we get a clear night and I put my eye to the eyepiece suddenly life is no longer mundane.

Your magazine has made me more aware — even on nights of supposedly poor seeing. I really enjoyed John Mood's articles in February and March because we get a lot of atmospheric phenomena here, and really clear nights are few and far between. You have kept the magazine as Stephen A. Walther would have wanted it.

Phil Douglas
Bluff Springs, IL

An Idea Whose Time Has Gone

Sir / The space program is under attack. Those of us in support of space exploration have anguished over the cancellation of project after project — several Apollo flights, Grand Tour (as originally designed), VOIR, etc. I felt, long ago, that the American people had a voice in this, that interest would revive and the situation turn around.

But realistically speaking, with administration after administration (of either party) seeing cuts in the space budget as a cure-all, perhaps we should consider space exploration as a historic concept, an idea whose time has come — and gone — rather than expending additional futile efforts trying to scrape something together. Perhaps it is better this way.

Alan D. Spitz
Phoenix, AZ

Messier Marathon

Sirs / On the night of March 27/28, members of the Westport (Connecticut) Astronomical Society gathered together for our third annual Messier Marathon on the grounds of a former Nike missile radar tracking installation. There, perched on top of one of two sixty-foot towers, is our observatory, housing a 12-inch f/6 Newtonian.

While most of the members present used this instrument, I opted for my 8-inch f/7 reflector with 26mm and 18mm Plossl eyepieces. To locate the objects themselves, I used *Sky Atlas 2000.* My 7x50 binoculars helped me locate the fields of the more southern objects.

As soon as dusk fell, I began a frantic search for the "early" M-objects. I was unable to locate M-74 and M-77, due to a crescent Moon in Pisces and sky glow from a pair of nearby cities. Other club members, using the 12-inch, glimpsed both M-74 and M-77.

After the evening "rush hour" was over, I stopped to breathe for a while. Then came the Realm of Galaxies. Using both the *Sky Atlas* and the AAVSO *Variable Star Atlas*, I conquered the Coma-Virgo cluster. During the morning rush hour, I found all of the late M-objects with the exception of M-30.

All in all, I spotted 107 of the 110 Messier objects plus 27 additional NGC objects. The other marathoners in our group located 97 M-objects plus an unknown number from the NGC.

The temperature was freezing, the wind intense, but everyone had a great time. In fact, with our high level of enthusiasm, we couldn't help thinking: "How about an NGC Marathon!"

Phil Harrington
Staten Island, NY

Astronomical Society of the Pacific

Sir / We enjoyed "Astro-Sources" in the May ASTRONOMY, but were disappointed that you omitted the Astronomical Society of the Pacific from your roster of organizations.

The A.S.P. is one of the oldest and largest astronomy groups in the world, and one of the few specifically designed to bring together professional, amateur, and "armchair" astronomers.

Andrew Fraknoi
Executive Officer, A.S.P.
San Francisco, CA

— Despite its regional name, the Astronomical Society of the Pacific is an organization with members in all 50 states and many foreign countries. Its omission from the list was an unfortunate oversight. Our apologies.

Anyone interested in the Society, its two fine publications, and the programs and services it offers should write for a free brochure. Address: Membership Secretary, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

Drumming up Telescopes

Sir / Here's something I'd like to pass on to owners of large telescopes:

To seal your tube against dust while your scope is in storage, use a drum head. They are available in sizes ranging from 10" to 24", and the right size will fit very snugly over the end of the tube.

Music stores sell drum heads for $12 to $15, with bottom heads usually a little cheaper. The better quality heads will withstand more impact and are virtually waterproof. I've also seen used heads selling for as low as $5 each, and should you find one that's beaten-up and marked (but not split), a quick coat or two of spray paint will dress it up nicely.

Charles Bunting
Shambaugh, IA

Ooops!

In April's "Alt-Azimuth Setting Circles," one part of the instructions can sometimes yield an erroneous value for the azimuth. When you check to see if the value for the azimuth should be subtracted from 360°, look at the *sine* of the hour angle. If it is positive, subtract the value derived from 360°; if the sine is negative, the value is correct as it is.

The photo of the -6 magnitude fireball on page 34 of the April issue was taken by Pekka Parviainen, not Hal Povenmire.

behind the scenes

credit where credit is due

"The Russians have landed."

"What?"

"On Venus — the Russians landed Venera 13. Everything worked. It lasted over two hours. They got back good pictures."

That's how I found out that Venera 13 had accomplished a successful mission to the hellish surface of Venus and returned color pictures comparable in quality to the images NASA received from the relatively benign surface of Mars. Clearly, Soviet capability in planetary science has improved steadily — and considering the political and language barriers, it wasn't hard to get copies of those pictures for ASTRONOMY.

Here in the U.S., we tend to think that other nations can't create, or excel, in technical expertise. When they do, we suspect them of somehow having "taken" it from us. But the laws of physics don't see things in political or ideological terms. What we can invent, they can invent; what we can do, anybody can do.

If Americans build computers, so can the Japanese. They may be making better microchips than we can in a few years. If Americans can make fundamental discoveries in atomic physics, so can the Europeans. They might make the next fundamental breakthrough. If Americans can target spaceprobes accurately, so can the Russians — and they may keep sending probes while we turn our backs on space for the next decade or two.

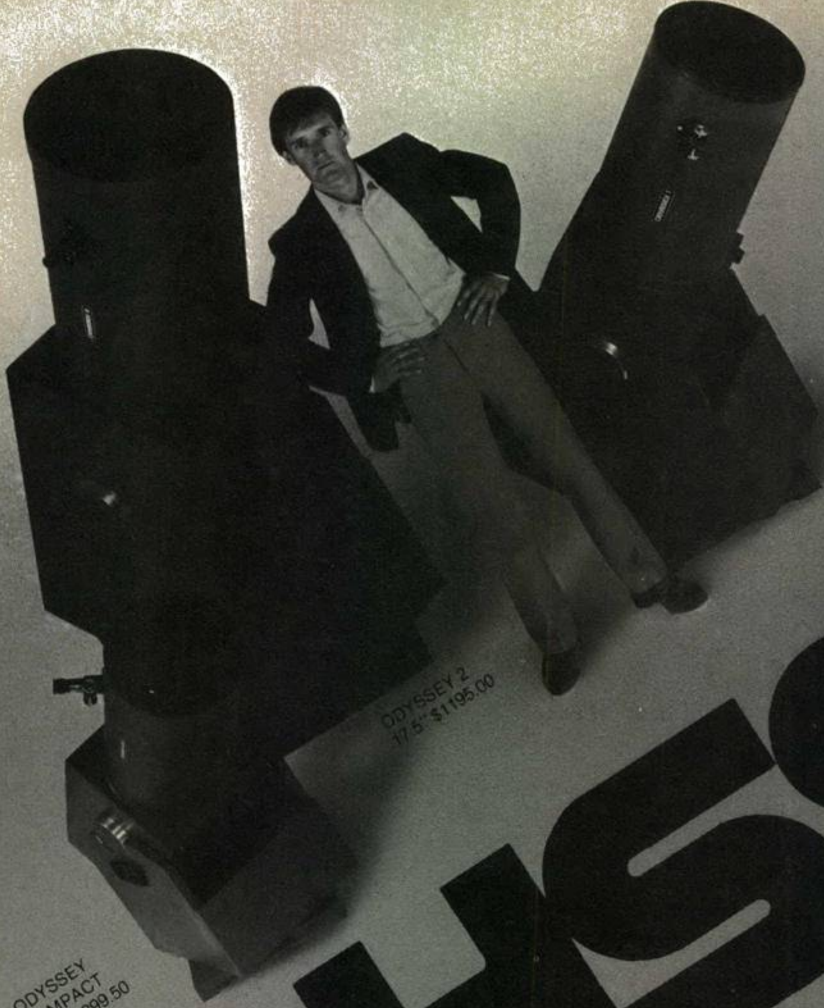
"So what?"

Two successful Russian landings on Venus convey exactly the same message that the American Viking and Voyager missions conveyed to the rest of the world. They proclaim: "We have know-how. We can do it. We're good at it." It's a message in peaceful terms — but one with military and economic ramifications. How the other peoples of the world will interpret that message and how they will respond we can only guess. The Russians — whatever else you may think about them — executed a technically difficult scientific mission to Venus. This time, at least, let's give credit where credit is due.

Sincerely,

Richard Berry

Richard Berry
Editor



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COSMOS 1

WRITE FOR DETAILS

do you really need an RFT?

by Michael Covington

One of the recent developments in backyard observing is the growing popularity of rich-field telescopes — reflectors specially designed for low-power, wide-field viewing.

Ten years ago, they were "specialty" items; few manufacturers made them, and only dedicated deep-sky observers and comet hunters bought them. But today, the 4-inch Newtonian RFT has displaced the old 2.4-inch refractor as the standard first telescope for beginners, and ready-made models or components are available for instruments up to 17.5" aperture. Nor are they just for beginners: many experienced observers have RFTs that double as auxiliary telescopes.

But why would anybody want a low-power telescope? Many beginners wonder about this, especially if they've been exposed to the old "high-power" school of telescope salesmanship. You know — "See the Moon Close Up!" "Gives 900X!!" "See Stars Hundreds of Light-Years Away!!!"

But anyone who looks through a telescope at high power immediately notices several disconcerting things including how sensitive it is to vibration, and the fact that the image is much dimmer at high power than it is at low power.

In the case of objects that have an appreciable angular size (terrestrial targets, the Moon, the planets), the reason for the dimness is that higher-power scopes simply spread the same amount of light out over a larger area.

And when you look at a field of stars at high power, the individual star images don't get any dimmer — optically, stars are points and form the same size image at all magnifications — but you do see fewer of them. This happens because you're taking a small region from the middle of a low-power field and magnifying it to fill the whole field of view — without adding any more stars to it.

With some objects, high powers are ideal. For example, observing planets and double stars generally requires as high a magnification as seeing conditions allow. But what if you want to look at large, dim objects like star fields, clusters, or nebulae? Then what you need is *brightness* rather than magnification, and it makes sense to use as low a power as you can.

If this is true, why not reduce the power without limit? If 50x is brighter than 100x and 25x brighter than 50x, wouldn't 10x be brighter still? For that matter, why not go all the way down to 5x or even 1x — think how spectacular the Milky Way would look if you could direct all the light gathered by a 17.5-inch telescope into your eye without magnifying the image!

Horsehead Nebula

Jack Newton

Unfortunately, you can't get away with it. The *exit pupil* imposes limits on the bundle of light rays that comes out of the eyepiece into your eye. To see an exit pupil, aim your telescope at the blue daytime sky and look at the eyepiece from a couple of feet away. You'll notice that not all of the eyepiece's outermost lens is illuminated — only a circular area in the center that covers perhaps half the diameter of the lens or less. The illuminated circle is the exit pupil of that eyepiece.

You can calculate the size of the exit pupil of any eyepiece used with your telescope by dividing the aperture of your telescope's mirror or objective lens by the magnification the eyepiece gives.

$$\text{exit pupil} = \frac{\text{aperture}}{\text{magnification}}$$

A 6-inch telescope at 30x has an exit pupil of 6 divided by 30, or 1/5" across. With a 60x eyepiece, the exit pupil diameter is 6 divided by 60, or 1/10". Exit pupils are larger at low power and smaller at high power.

And there's the catch: if the exit pupil is larger than the pupil of your eye, you aren't going to see all the light your telescope has caught. In fully dark surroundings, the pupil of your eye will enlarge to a diameter of about 7 to 7.5 millimeters. Thus the image you see in a telescope will get brighter

EXIT PUPIL	MAGNIFICATION for apertures of:										For this kind of observing:
(mm)	2.4"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	
0.5	120	200	250	300	400	500	600	700	800	900	1000	Planets under exceptional conditions, close doubles
1	60	100	125	150	200	250	300	350	400	450	500	Planets and double stars
2	30	50	60	75	100	125	150	175	200	225	250	General viewing (probably your most useful eyepiece)
5	12	20	25	30	40	50	60	70	80	90	100	Rich-field viewing: clusters, nebulae, star fields
7	9	14	18	21	28	36	44	51	58	65	73	Practical limit: lowest usable magnification

as you lower the power until the exit pupil diameter reaches about 7mm. If you reduce the power further, the image won't get any brighter because your eye can't take in the extra light.

What does the "7mm limit" mean in practice? In general, the magnification that gives a 7mm exit pupil is about equal to 1.4 times the diameter of your telescope in centimeters, or 3.5 times its diameter in inches. The lower limit is about 14x for a 4-inch telescope, 21x for a 6-inch, 28x for an 8-inch, and so on.

It looks as if all you need is a low-power eyepiece and you're in business, but it isn't quite that simple. Here's why: the magnification of a telescope is equal to the focal length of the telescope divided by that of the eyepiece:

$$\text{magnification} = \frac{\text{telescope f.l.}}{\text{eyepiece f.l.}}$$

or, to put it another way,

$$\text{eyepiece f.l.} = \frac{\text{telescope f.l.}}{\text{magnification}}$$

If you combine this formula with the first one we gave, you find that the eyepiece needed to give a particular exit pupil size is:

$$\text{eyepiece f.l.} = \text{exit pupil} \times \left(\frac{\text{telescope f.l.}}{\text{aperture}}\right)$$

So, for a given exit pupil size (7mm in our case), the eyepiece focal length you need depends on the telescope focal length divided by the aperture — a quantity usually known as the f/ratio of the telescope.

$$\text{eyepiece f.l.} = \text{exit pupil} \times \text{f/ratio}$$

If you fit the particulars of your telescope into this last formula — and your telescope isn't an RFT — you'll probably find that you need a longer focal length eyepiece than anyone manufactures. If you have an f/8 telescope, you'll need a 56mm eyepiece — and there's no such thing, at least not in the standard 1.25" diameter barrel. The longest eyepiece made in the standard size has a focal length of 50mm. So you need a scope with an f/ratio no higher than f/7 to get a 7mm exit pupil. But examine some other possibilities.

Even if you can find an extra long focal length eyepiece, the diameter of the eyepiece tube in your focuser still places a limit on the field of view. Think of an eyepiece as a magnifying glass that you use to look at the image the telescope forms. This image cannot usefully be any larger than the eyepiece tube, and if the eyepiece focal length is too long, you get a tunnel-vision effect because your *apparent field* will be too narrow. The real image won't be magnified to a comfortable size and you'll feel as though you're looking down a long, narrow tube.

Most eyepieces give an apparent field of view of about 50°. If your telescope has the usual 1.25" focusing tube, the field lens of the eyepiece can't be more than about an inch across, and the longest practical focal length is about 40mm. This gives a narrow but tolerable apparent field of 35°.

If your telescope takes import standard eyepieces — 0.965" (24.5mm) diameter — you'll squeeze your image even more. Although a 40mm eyepiece is available, the apparent field of view is uncomfortably small.

With standard diameter eyepieces, the practical focal length limit of 40mm gives you a 7mm exit pupil with an f/6 telescope, but not with an f/8 or f/10. One obvious solution is to make the eyepiece tube bigger. If you convert your telescope to take 2" diameter eyepieces, you can go up to 75mm focal length.

But this approach means you need a telescope that will produce an image two inches across. This poses no problem with catadioptrics — Schmidt-Cassegrains or Maksutovs — and is generally feasible with refractors or a conventional Cassegrain. And if you want to convert a refractor to take 2" eyepieces, you'll have to enlarge the glare stops in the tube. With these telescopes, the deterioration of image quality toward the edges of the field usually isn't too severe.

With a Newtonian, you face the problem that the diagonal mirror has to be big enough for a 2" image — roughly, a diagonal with a 2" minor axis. This will obstruct three times as much light as the slightly-less-than 1.25" diagonal of most small telescopes.

Two-inch eyepieces can produce superb results since they are usually of

EYEPIECE FOCAL LENGTH (mm) for scopes with f/ratios of:

f/4	f/6	f/8	f/10	f/12	f/15
(2)	(3)	4	(5)	6	8
4	6	8	10	12	15
8	12	16	20	24	30
20	30	40	50	(60)	(75)
28	40	(60)	(70)	(80)	(105)

The accompanying table gives recommended magnifications for viewing with different sized telescopes. You don't have to use the exact powers or focal lengths listed in the table; these are suggestions and only the maximum and minimum represent actual limits. The choice of eyepieces in between is up to you.

Focal lengths that aren't manufactured in standard sizes — such as 2mm or 75mm — are shown in parentheses. If you want the equivalent of an ultrashort eyepiece, remember that a Barlow lens doubles or triples the magnification, and this is equivalent to dividing the eyepiece focal length by two or three. For instance, to get a 2mm eyepiece, try a 6mm and a 3x Barlow.

If you want to start with a set of three eyepieces rather than all five, use the middle three in the table — those with 1mm, 2mm, and 5mm exit pupils. But whatever you do, make sure that at least one eyepiece — preferably in the middle range — is the best you can afford. To a great extent the crispness of the image you see, and the comfort your eye feels while observing, depends on your eyepiece rather than your telescope.

Here's how to use this table: Suppose you have a 6-inch f/8 telescope. If you go to the line labeled "general viewing" in the center column and scan left to the "6" column, you'll see 75. This is your general viewing power. In the far left column, you'll see that 75x will have a 2mm exit pupil. Now stay on this same line, but look to the right of the center column. Under the heading "f/8," you'll find that a 16mm focal length eyepiece is what you need to get 75x.

Similarly, let's suppose you have a 20-inch f/5 and want to have a 5mm exit pupil. This puts you on the "rich-field viewing" line and the power you want will be 100x. When you interpolate between the figures for f/4 and f/6 on the right-hand side of the table, you'll find that you need a 25mm (1") focal length eyepiece to get this magnification.

excellent optical quality. The most spectacular view of M-42 I've ever had was through a 12.5-inch Cassegrain with a 2" diameter Erfle eyepiece. Wispy tracery filled the field, and I felt like I was approaching the nebula in a spaceship.

I recommend 2" eyepieces if you're building an 8-inch or larger telescope and can plan for them in the design. But they are expensive; it isn't uncommon to pay $100 for a single eyepiece, and the extra cost of equipping a telescope with a 2" focuser, a 2" diagonal, and a couple of 2" eyepieces can run to $300 or $400 — enough to buy another telescope.

Fortunately, you have an alternative: the compressor lens, or rich-field adaptor. This is a positive lens inserted into the converging cone of light from the objective mirror or lens before it reaches the focal plane. A compressor lens is the exact opposite of a Barlow — it reduces the magnification and f/ratio rather than increasing them. If you're trying to get an RFT view with an f/10 or f/15 telescope, it's really helpful. The idea is to take a 2" wide beam of light and squeeze it down into something small enough to go through a standard size eyepiece.

To use a compressor lens in this way, you need a 2" wide light beam just as you did with a 2" eyepiece. You'll also need to position the lens several inches in front of the focal plane. This is easy with a catadioptric and a minor bother with a refractor or conventional Cassegrain — but it's next-to-impossible with all but the largest Newtonians. Of course, typical Newtonians have relatively short focal ratios — around f/6 — so you don't need a focal compressor lens with them.

Telecompressors also sacrifice a little optical quality, but most observers find this an acceptable trade-off. For photography, compressor lenses are a real boon; if you cut the f/ratio in half, you can cut the exposure time by a factor of 6 to 8, depending on the amount of reciprocity failure in your film. (See "All About Telecompressors," ASTRONOMY, February 1981.)

Today's typical RFT is a 4-inch Newtonian with an f/ratio of about 4. It gives a 7mm exit pupil with a 28mm eyepiece and has a magnification of about 15x. In such an instrument the field of view is about 3° across, and the sights you'll get of rich star fields such as those in Sagittarius or Canis Major can be absolutely breathtaking. And these scopes are compact — less than a foot-and-a-half from end to end — and require only a good camera tripod as a mounting. Larger models, usually on a Dobsonian mount, aren't as easy to lug around, though they still fall within the "portable" category.

The main disadvantage of any RFT is that not all eyepieces work well with short f/ratio optics. The telescope's optical system, at least on axis, should still produce perfect, diffraction limited images. But the sharply converging cone of light from an f/4 objective will bring out aberrations in an eyepiece that would be insignificant at f/10.

An extreme example of this is the Huygenian eyepiece design, which consists of two simple lenses. This set-up is common and inexpensive, but requires an f/ratio of f/10 or higher to work well. As a result, only refractor and catadioptric telescope owners are generally able to put them to good use.

What kind of eyepiece do you use with an RFT? Many handbooks say that Kellners are best and that orthoscopics should be avoided, but my experience has been just the opposite. I get excellent performance using an 18mm orthoscopic eyepiece with my 4¼" f/3.5 Newtonian — better, in fact, than with a Kellner. So it seems to depend on the individual eyepiece. If you can, try them before you buy.

Erfle eyepieces are often used with low f/ratio systems and I have heard that observers get excellent results with Plossls. I also know from experience that the 28mm RKE gives beautifully crisp images. And it has a lot of "eye relief" — the distance from the eyepiece that you must hold your eye to see a fully illuminated field of view. Observers who wear glasses like a lot of eye relief; those with normal vision prefer less. But it's hard to give any general advice about eyepieces. The best way to learn about them is to ask fellow telescope users, look through their instruments, and try a few out yourself.

The fact that most RFTs don't perform well at high powers is related to the eyepiece problem. High powers exaggerate the aberrations in a short-focal-length optical system. You have

North America Nebula

E.A. Roberts

to remember that RFTs weren't designed for scrutinizing the Moon, planets, and double stars — but they work fine for casual viewing.

So far, we've been assuming that using the full 7mm exit pupil is a good idea. But this isn't always true. The cornea and lens of your eye are less transparent and more subject to optical imperfections around the edges than in the center. So if you insist on using the full diameter of your eye's optics, you won't get maximum image quality. And, besides, how can you be sure that your eye is open to 7mm all the time anyway?

One reason why that streetlight across the road is such an annoyance when you're observing dim nebulae is that it keeps your pupils from dilating fully. Every time you light-blitz your eye, the pupil contracts. It will open up again a few seconds later if you keep light away from it, but when your pupil is constantly opening and closing, its average aperture will be less than the ideal 7mm.

Dark adaptation, by the way, is distinctly different since it involves the release of extra light-sensitive chemicals in the retina. Full dark adaptation takes half an hour or more to achieve.

Another problem: the exit pupil of a reflector or catadioptric telescope has a "hole" or dark spot in the middle of it, which corresponds to the obstruction of the secondary mirror in the light path. With a 4-inch Newtonian, this hole is about a third the diameter of the exit pupil itself — a 7mm exit pupil has a 2.3mm hole in it.

Suppose you're using this telescope for daytime birdwatching and the pupil of your eye, constricted by the bright ambient light, is only 2mm across. You guessed it — when you put your eye to the eyepiece and center it perfectly, you won't see anything at all because you'll be looking at the hole! If you want to use your reflector for daytime viewing, or even for looking at the bright Moon, you'll need to use a higher power to make a smaller exit pupil. Still another problem occurs for older observers. Once you pass 30, your pupil's maximum opening decreases. By the time you're 50, your pupil probably never exceeds 5mm in diameter.

For these and other reasons, I have settled on a 5mm wide exit pupil rather than 7mm for my own rich-field viewing. With a wide-angle Erfle eyepiece, the actual field of view need be no smaller than it is at 7mm, and the image looks clearer. Also, it's easier to get a 5mm exit pupil with standard eyepieces than it is a 7mm one.

But even this isn't always the best power to use for hunting faint nebulae and galaxies. All other things being equal, a large, dim object is easier to see than a small, not-quite-as-dim object. If your target has relatively little angular extent, you may need a high power just to identify it. This is commonly the case with galaxies.

Just the same, RFTs are ideal for many reasons. It's hard to beat them for portability, and they make good second telescopes. I frequently sweep for clusters and nebulae with my RFT while I'm taking a "piggy-back" star-photo with my other telescope. These photos don't often require continuous guiding, so I'm free to scan here and there through the star-fields while the exposure is running.

An RFT is also the best instrument for viewing large, faint nebulosities and large, scattered star clusters. M-31, the Great Galaxy in Andromeda, is the most prominent of these. Only an RFT will get a sizeable fraction of the whole galaxy into one field of view, while still magnifying it enough to show an interesting amount of detail.

The Veil and North America Nebulae in Cygnus are ideal RFT targets when the sky is exceptionally clear. The Milky Way is majestic under even ordinary conditions. I remember exploring Puppis one evening with a star atlas and getting impressive views not only of Messier clusters, but all the NGC objects as well — plus some that didn't even make it into the *Catalogue*.

And one chilly evening I detected a faint misty patch near Zeta Orionis. By wobbling the telescope back and forth and using averted vision, I picked up an even fainter brightening of the sky background just south of the star. Carefully putting Zeta out of the field, I managed to glimpse an obscuration or notch in the nebulosity.

Then I went to an atlas and found out what I'd been looking at: with a 4-inch telescope — 2 inches less than the supposed minimum necessary aperture — I had seen the Horsehead Nebula.

Michael Covington has been an active astrophotographer for 12 years and spends his spare time gazing at nebulae and galaxies from his native Georgia.

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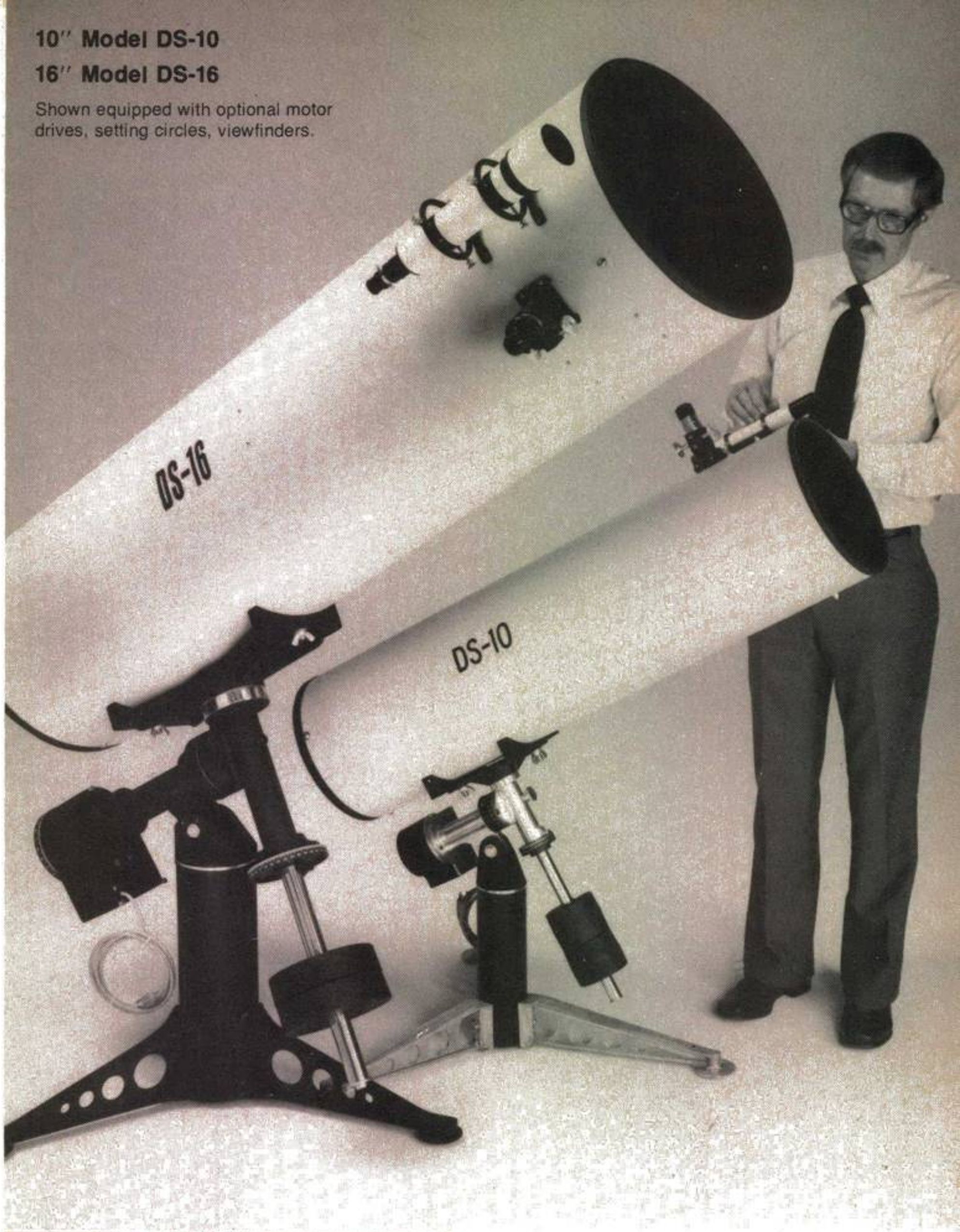

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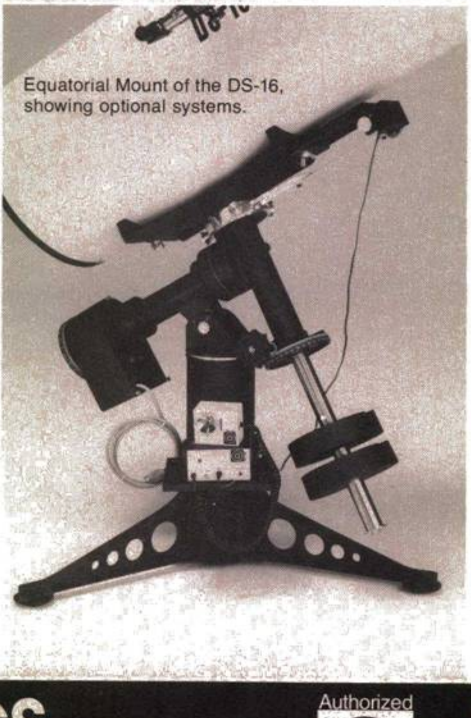

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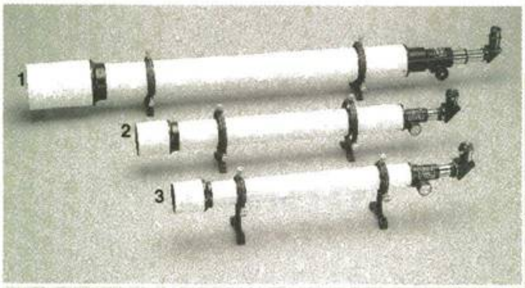

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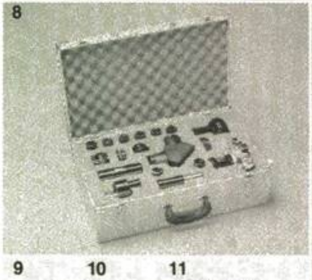

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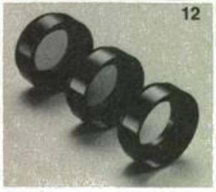

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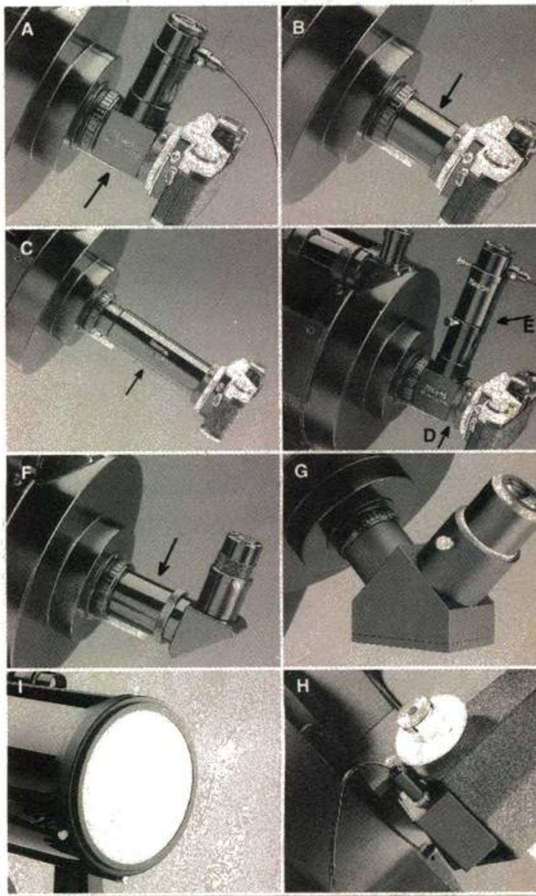

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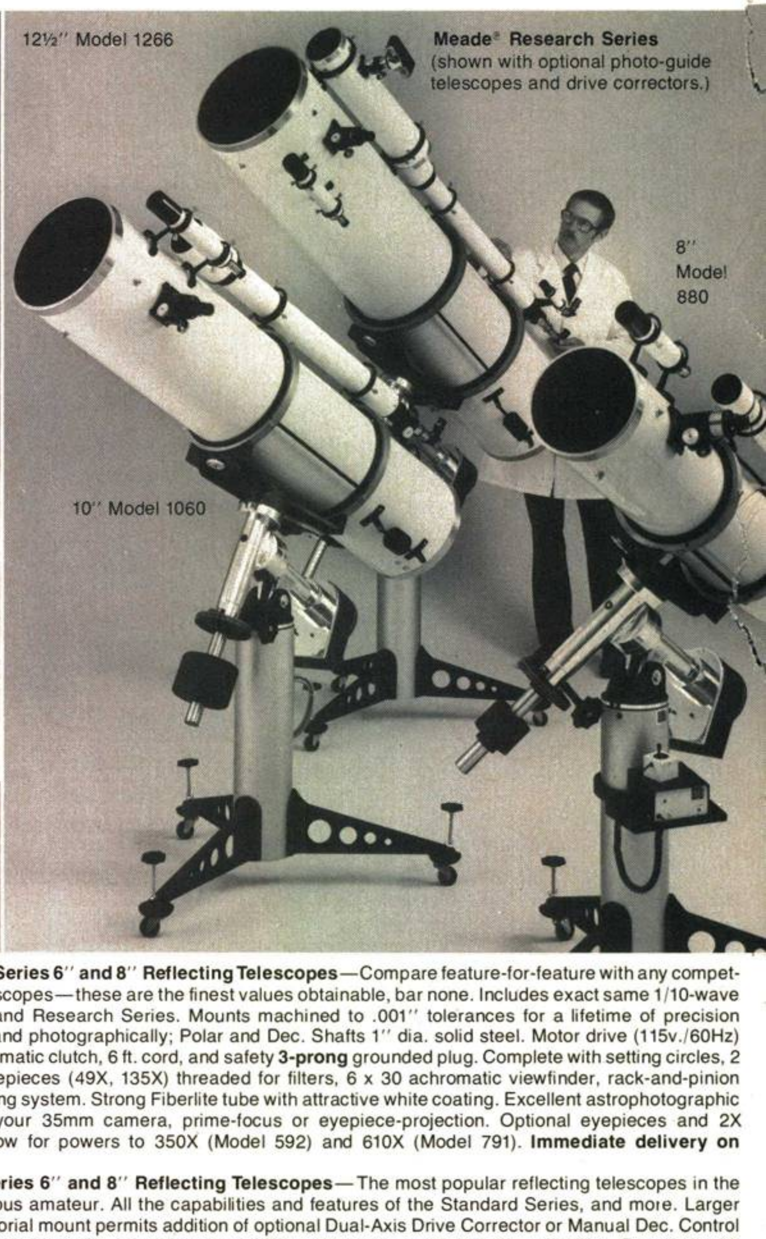

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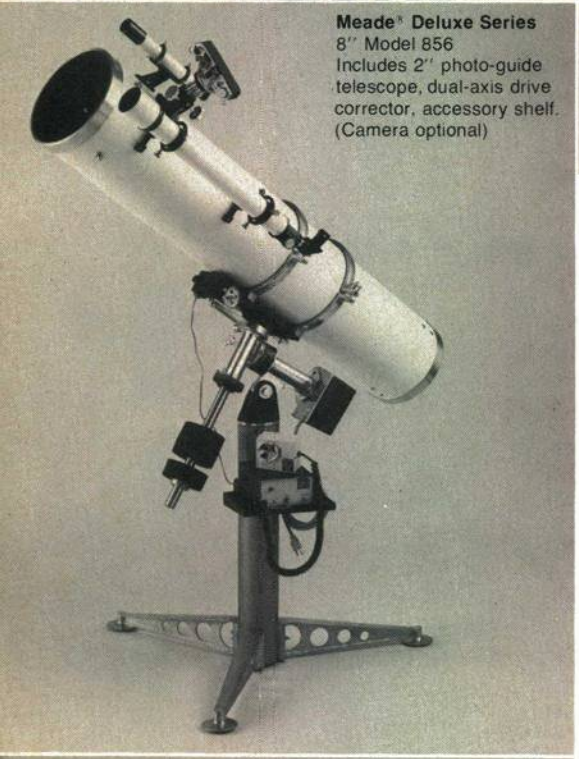

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july's long lunar eclipse

gazer's gazette

Eclipses of the Moon offer one of the most relaxing ways to enjoy a few hours of skywatching. Their pace doesn't rush you — they usually last more than an hour — and their changes are subtle and slow. You won't need a telescope either, because the whole show is best with your naked eye.

North American observers have waited seven years for this look at the eclipsed Moon; it should be one of the most impressive of the decade. This blockbuster begins on the night of July 5 and carries over into the next morning. You couldn't ask for a better time of year, and with clear skies, nearly everyone will have a chance to view at least some part of lunar totality.

Lunar eclipses occur when the Earth passes between the Sun and the Moon, causing the shadow of our planet to obscure the Moon. These eclipses happen only at Full Moon, but not every month, because the lunar orbit is inclined to the Earth's orbit around the Sun. Since the cone-shaped shadow of the Earth trails out many millions of miles behind our planet, the Moon can enter the shadow cone at varying points.

Some lunar eclipses are not total, because the Moon passes only through the lighter part of the Earth's shadow, or *penumbra*. But this eclipse *is* total and should be spectacular since the Moon passes through the darkest part of the shadow — the *umbra*.

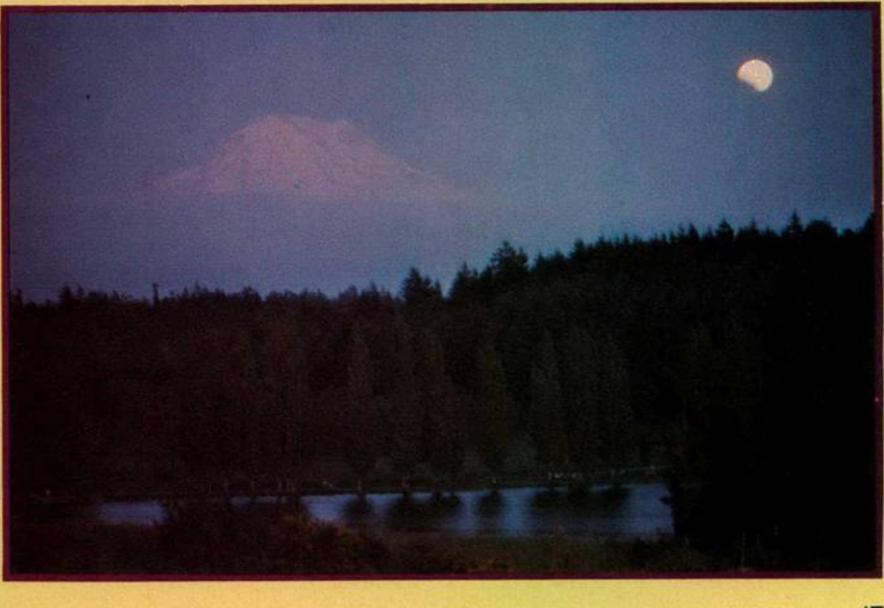
One factor clearly affects the darkness of a lunar eclipse — the 5° inclination of the Moon's orbit to the Earth. This inclination causes the Moon to cross through the plane of the Earth's orbit at two different points, or *nodes*. At one point, the Moon crosses the Earth's orbital plane from south to north — this is the *ascending node*; a north to south crossing is a *descending node*. When the Moon is close to a node, it is also close to the Earth's orbital plane. The Moon's proximity to one of these nodes prior to an eclipse affects the angle that it takes on its passage through the Earth's shadow. It may just nick the edge of the shadow, or it may go right through the center.

For this eclipse, the Moon becomes Full only minutes after it crosses the descending node. Such close timing insures the Moon will pass through the middle (and darkest) part of the umbra. In fact, July's eclipse will be more central than any since 1906!

But what does this mean visually? For one thing, the appearance of the Moon will change, and at mid-totality may be anywhere from nearly invisible

ECLIPSE TIMES	EDT	CDT	MDT	PDT	ADT	HI/ST
First penumbral	12:22	**11:22**	**10:22**	**9:22**	**7:22**	**6:22**
First umbral	1:33	12:33	**11:33**	**10:33**	**8:33**	**7:33**
Totality begins	2:38	1:38	12:38	**11:38**	**9:38**	**8:38**
Mid-eclipse	3:31	2:31	1:31	12:31	**10:31**	**9:31**
Totality ends	4:24	3:24	2:24	1:24	**11:24**	**10:24**
Last umbral	5:29	4:29	3:29	2:29	12:29	**11:29**
Last penumbral	6:40	5:40	4:40	3:40	1:40	12:40

Boldface times are p.m. July 5; all others are a.m. July 6.



The partially eclipsed Moon rises beside Mount Rainier on May 25, 1975, when the U.S. had its last good view of lunar totality. This month's eclipse will surpass any other since 1906. Max Heinzmann used a 135mm f/2.8 lens and a ⅛-second exposure on discontinued High-Speed Ektachrome, ASA 160.

to bright orange. Not only will the Moon change colors, but it will also drop in magnitude, so fifth or sixth magnitude stars will pop into view, even though the Moon is still in the sky. The ruby-red Moon bejeweled by the bright summer sky will be memorable, but it's hard to predict exactly how bright or dim the Moon will get during the eclipse.

The French astronomer A. Danjon developed a scale you can use to judge the naked-eye brightness of the eclipsed Moon. Just note the Moon's appearance during various stages of totality, and then fit it into one or more of these classifications:

L = 0: A very dark eclipse with the Moon practically invisible at mid-totality.

L = 1: A dark grey or brownish eclipse; lunar details are distinguishable only with difficulty.

L = 2: A deep red or rust colored eclipse with the central part of the shadow very dark and the outer edge of the umbra relatively bright.

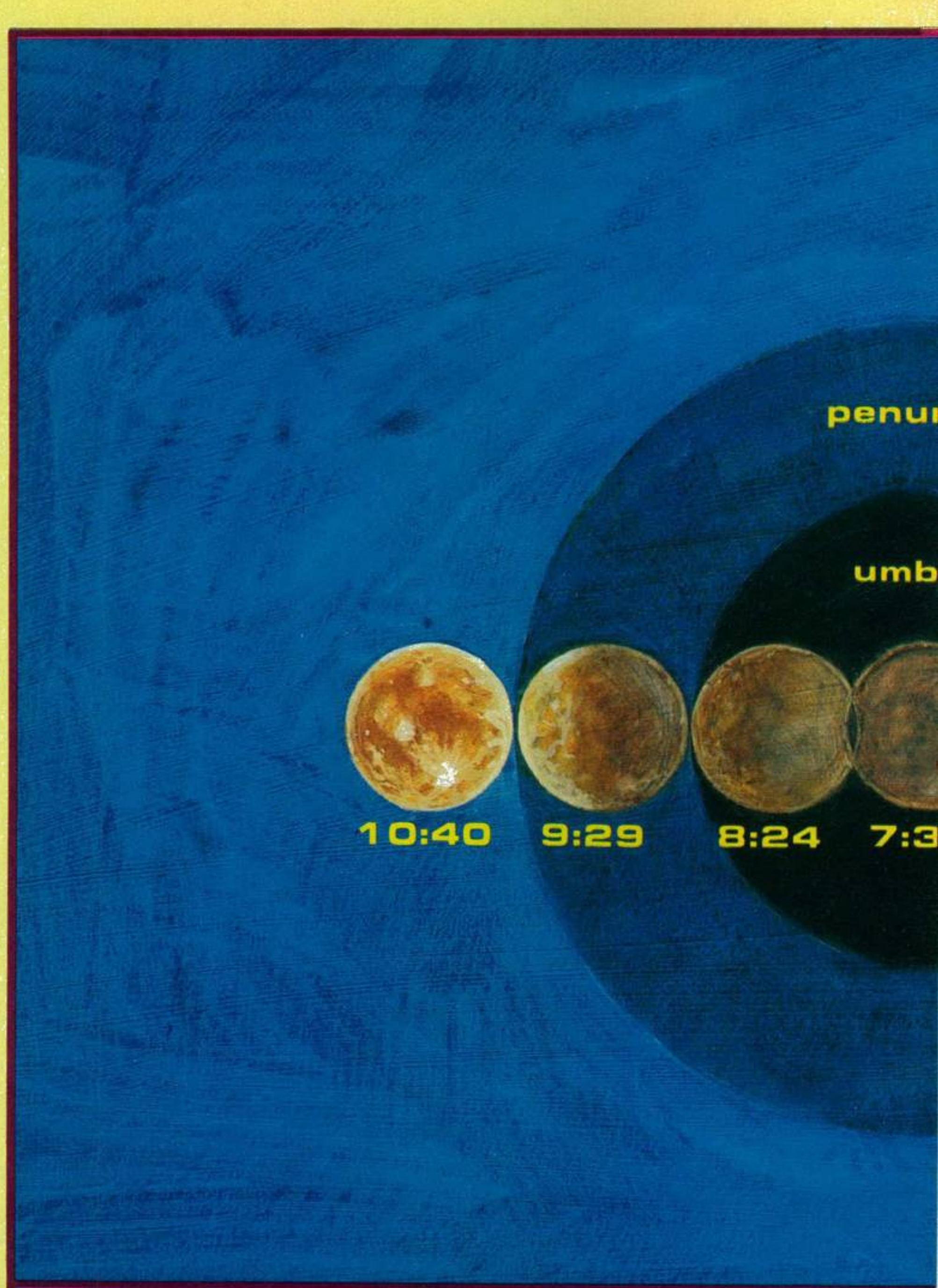
L = 3: A brick-red eclipse, usually with a bright grey or yellow rim to the Earth's shadow.

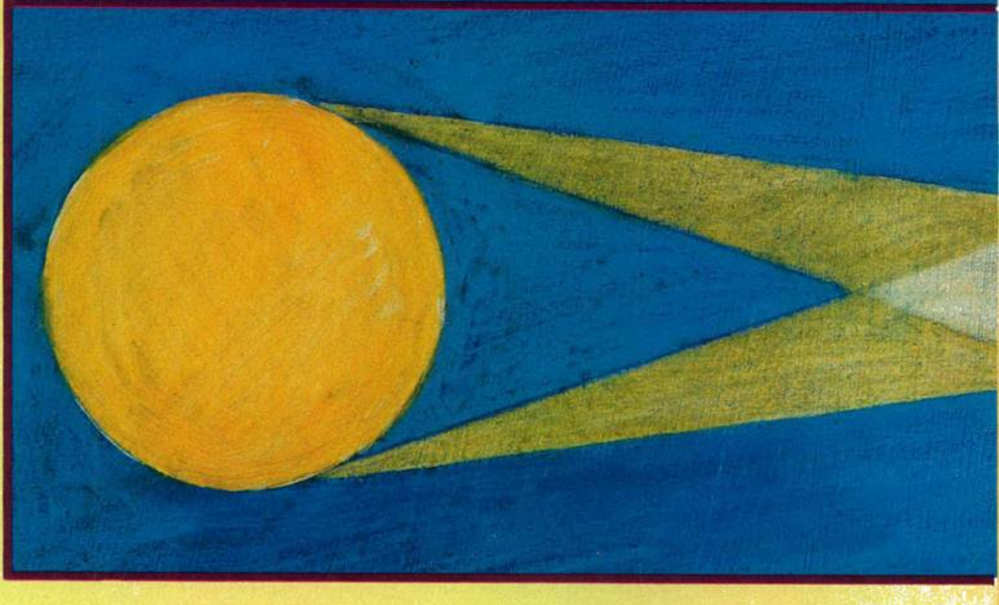
L = 4: A very bright copper red or orange eclipse with a bluish, very bright edge to the Earth's shadow.

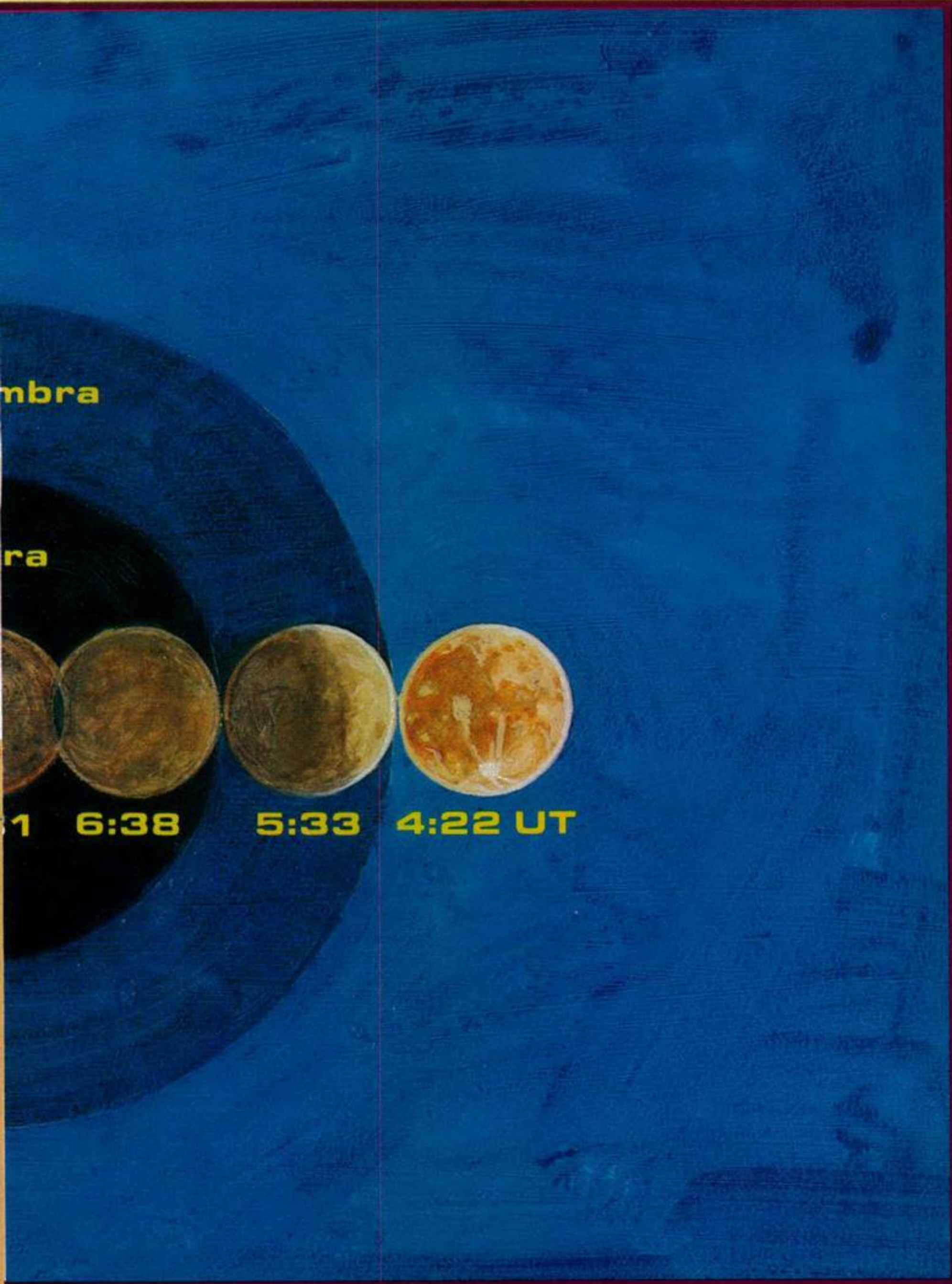
Weather during an eclipse night can have a major effect on the color and intensity of the umbra. Pollution and clouds in the Earth's atmosphere block light; the more they absorb, the darker the eclipse will be. The reddish color that characterizes an eclipse is produced in the same way that red sunsets are — our atmosphere absorbs green and blue rays of light, but lets red pass through. Be observant from the start of the eclipse and you'll see the different effects produced by the two parts of the Earth's shadow.

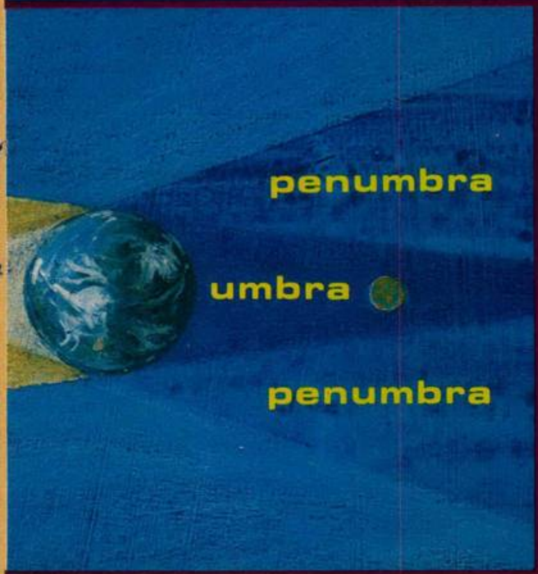
To enjoy your night of observing to its fullest, remember to dress warmly and bring along a comfortable chair. First penumbral contact is at 4:22 UT. You won't notice much change for at least half an hour. Try to judge the exact time you see the penumbra — that will be the start of the eclipse — but don't expect any excitement until the limb of the Moon enters the umbra. Predictions indicate this will happen at 5:33 UT. Watch for that first "bite." From now until totality begins, the eclipse seems to progress much faster. The 146 minutes of totality, beginning at 6:38 UT, will fly by.

The Moon quickly becomes inflamed as the Earth's shadow engulfs it. Its hue changes dramatically from yellowish-white to increasingly darker shades of orange and red. Although astronomers can't predict the exact degree of darkness, they are fairly sure this eclipse will be a dark one — ash from Mt. St. Helens and other volcanos is probably still floating around in the









At left is the configuration of the Sun, Earth, and Moon that produces a total lunar eclipse. Above: the path the Moon takes through the Earth's shadow during this eclipse is nearly central. First penumbral contact is at 4:22 UT (right side of diagram). The Moon will then move steadily into the darker part of the shadow — the umbra. Top right: the eclipsed Moon immersed in a starry field. Steve Fahnensteil used a 135mm lens at f/3.5 and a 5-minute guided piggyback exposure for this mid-totality photo of the May 1975 eclipse. Middle right: the Moon with just a hint of sunlight left on the limb. R. Steeg used a 10-second exposure on Ektachrome 400 film at the prime focus of his 8-inch f/5. Right: an entire eclipse on one frame. Dan Ostergaard used a 4x5 Speed Graphic with a 152mm lens and ASA 100 film. The first two exposures were 4 seconds at f/5.6; the last were 1/50 second at f/8.

stratosphere.

At 7:31 UT the eclipse reaches its darkest — mid-totality. Since the event occurs in Sagittarius, you may be able to capture not only the darkened Moon, but also the summer Milky Way all in one dramatic photo. The Moon will seem almost translucent as it hangs eerily suspended above the Teapot. This will be the best time for long-exposure guided photographs of the eclipsed Moon in a starry field. Of course, if the Moon is not much dimmed, you won't get such dramatic pictures.

Mid-totality is the height of the eclipse. After that you see the first half in reverse. Totality ends at 8:24 UT, and last umbral contact is at 9:29 UT. By then the Moon has returned to near normal brightness, though some penumbral shading remains.

If you want to time the four umbral contacts precisely, you must carefully monitor the appearance of the lunar face from the beginning of penumbral immersion, and determine the precise moment the Moon enters the umbra. Telescopic observation will help you detect this subtle difference in shading.

Time the point that the Moon's limb first enters the umbra, then the time the following edge enters. After the second contact, the Moon will be fully eclipsed. Also note the time the first edge leaves the umbra, and then the last edge, which signals the end of totality.

By now you're probably covered with dew, and may have suffered a few mosquito bites, but you've seen the Great Lunar Eclipse of 1982. Although there is another total lunar in December, conditions won't be nearly as favorable for that one. You'll have to wait a long time before you can once again see the eclipsed Moon suspended before the Summer Milky Way.

— *Berry Brunk*

shoot the moon

You won't need fancy gadgets to take spectacular photos of this month's eclipsed Moon among the stars of Sagittarius — just a tripod and a camera that can make time exposures. You'll want to use color film to record the shades of red and brownish-orange that only occur during a total lunar eclipse; any ASA 400 color film will give good results. Use a tried and true brand, because you don't want to experiment with a new "wonder film" during a special event like this. You might end up spoiling this opportunity to add to your collection of astrophotographs.

The assortment of lenses in your camera bag will dictate the kind of eclipse photo you'll get. Remember that the Moon is a very small object. When you photograph it with a 50mm "normal" camera lens, the image of the Moon is only 0.5mm across on the negative. If you're limited to this focal length lens, try for a sequential photo that shows the progression of the Moon as it heads into and out of totality. You can make all the exposures on one frame, but you'll tie up a camera for the entire evening.

For this shot set your lens at f/5.6 and open the shutter at ten minute intervals with increasingly long exposures as the Moon heads for totality; then decrease exposures as it re-emerges. A range of 1/250 second during penumbral phases to a full second at mid-totality will give good results.

You can also produce a trail of the Moon throughout the whole eclipse. Set your lens on f/16 and lock the shutter open for the duration of the eclipse. Your picture will show a trail of varied color and width across the frame.

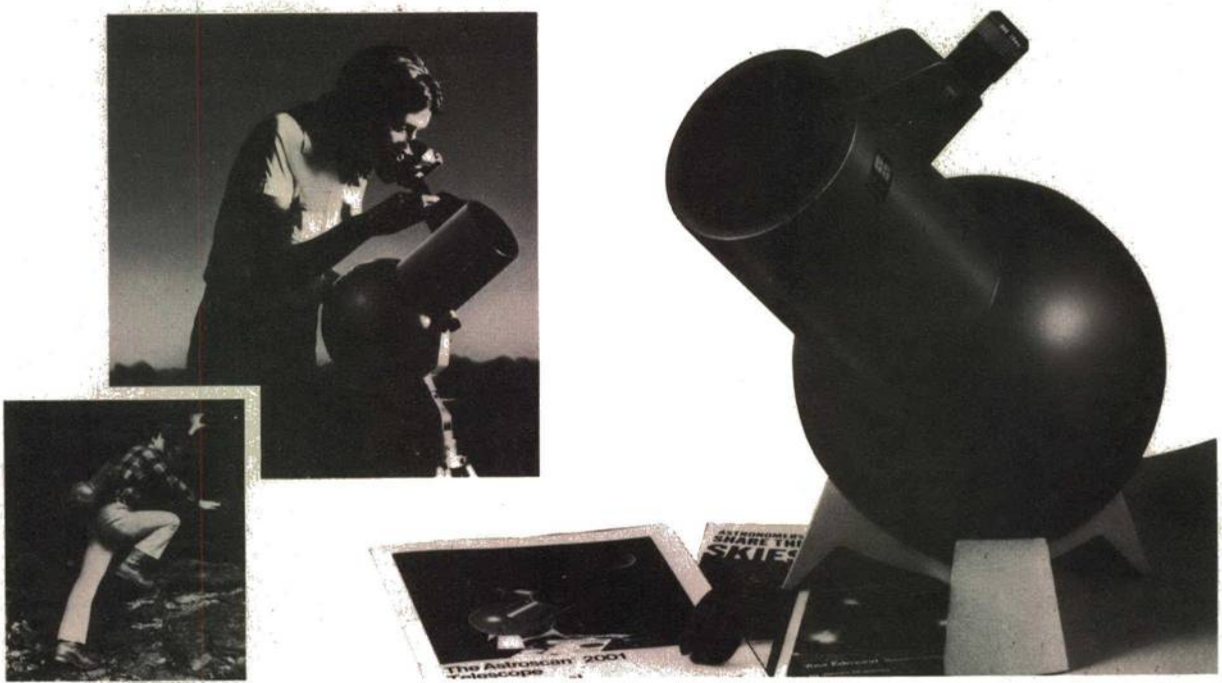
You'll need a lens of at least 300mm to put a good sized image of the Moon on film. The longer your lens, the more detail you can record. If you shoot the eclipse through your telescope, you'll want to use the prime focus method. Simply attach the camera to the eyepiece drawtube and focus carefully. If you have a clock drive, turn it on because the Moon will become dark at mid-totality and you'll have to use exposures several seconds long. The Moon's appearance at the time of eclipse is the determining factor for exposures. Just remember to bracket — the final product will be worth the few frames that didn't come out.

A 6-inch f/8 telescope gives you a prime focus image of the Moon nearly a half-inch across — big enough to show all the maria and many craters. Exposures of 1/250 second are fine until the Moon enters the umbral phase. Setting your exposures will get tricky now since we don't know exactly how dark the Moon will get. Depending on the Moon's magnitude, you'll want to try exposures ranging from 1/30 second to 10 seconds at f/8 as the eclipse progresses through totality. And just to make sure you get one that's perfect, try a wide range of exposures.

Location	Lat/Long	6h38m (UT) Start of Totality	8h24m (UT) End of Totality
Boston	42N, 71W	20°, 207°	8°, 229°
New York	40N, 74W	22°, 205°	11°, 227°
Toronto	43N, 79W	21°, 200°	11°, 222°
Miami	25N, 80W	38°, 202°	25°, 226°
Pittsburgh	40N, 80W	24°, 199°	14°, 222°
Atlanta	33N, 84W	32°, 196°	21°, 220°
Chicago	42N, 87W	24°, 192°	16°, 216°
St. Louis	38N, 90W	28°, 189°	20°, 214°
New Orleans	30N, 90W	36°, 190°	27°, 216°
Houston	29N, 95W	37°, 184°	30°, 212°
Winnipeg	50N, 97W	16°, 182°	-0.4°, 301°
Denver	39N, 105W	27°, 173°	25°, 200°
Phoenix	33N, 112W	32°, 165°	32°, 194°
Calgary	51N, 114W	14°, 165°	15°, 190°
Los Angeles	34N, 118W	30°, 159°	32°, 187°
San Francisco	37N, 122W	26°, 156°	30°, 183°
Vancouver	49N, 123W	14°, 157°	17°, 181°
Anchorage	61N, 150W	- 4°, 134°	3°, 156°
Honolulu	21N, 158W	17°, 124°	35°, 141°

(0° = North, 90° = East, 180° = South, and 270° = West)

This table shows the Moon's altitude and direction as it is eclipsed. Northern viewers note that at the end of totality the Moon will be close to the horizon and will soon set.



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ASTRONOMY
REVIEWS

Revealing the Universe
James Carroll and
Alan P. Lightman
246 pages, hardcover, $17.50
MIT Press (1982)

Humans have been trying to understand the universe for a long time, but only in the last few centuries have we made much progress. The key was striking the right balance between the way we think about the universe and the way we observe it.

Egyptians, Babylonians, Mayans, and Chinese observed the stars systematically for centuries, but made little progress in understanding them because their way of thinking was inadequate. The Greeks, on the other hand, theorized brilliantly about the universe, but overemphasized the power of pure thought to the neglect of observation. They, too, got stuck.

Only when the Greek way of theorizing was combined with Francis Bacon's methods of observing and experimenting did astronomy — and all science — begin to flourish. Today, progress in astronomy still depends on making theory and observation work together. As Kant said, "Concepts without factual content are empty; sense-data without concepts are blind. By their union only can knowledge be produced."

Revealing the Universe explores the interaction of theory and observation as it occurs today on the frontiers of astronomy. In doing so, it traces the development of Einstein's theory of relativity and conveys current ideas about quasars and black holes, X-ray bursters, the Sun's corona, the evolution of the solar system, and the age and structure of the universe.

In this book, each of these topics is addressed by two authorities — one a theorist and the other an observer. As the editors state in the preface, and as Owen Gingerich shows in his chapter on the history of astronomy, theory and observation do not always proceed in a neat, systematic way. Instead, the path is often complicated and full of prejudices, ambiguities, blind alleys, overlooked answers, and accidental discoveries. Yet as you read the book, you begin to see that this complex process of interaction holds a few basic patterns:

First, *theory can lead, and observation follow.* For instance, Einstein developed relativity, not in response to observations, but out of a philosophical distaste for the structure of prevailing theory. Einstein's theory was then confirmed by measurements of the Sun's deflection of starlight and eventually accepted.

But philosophical distaste is a tricky guide; on one occasion, it led Einstein to reject his own theory's implication that the universe is expanding, until observations forced acceptance of it.

Second, *observations can lead, and theory follow.* When observations began to suggest that the Sun's corona might be very hot, theorists tried to avoid this conclusion, since it seemed to violate the second law of thermodynamics. How could a 6000° C solar surface heat the corona to 1,000,000° C? When evidence for a hot corona became undeniable, theorists developed a shock-wave theory. When new observational techniques undermined this, theorists developed a magnetic field theory. Each time, observation drove theorists back to their blackboards for an explanation.

Third, *theory and observation can develop separately until someone puts them together and discovers they fit.* Although black holes were a theoretical deduction from relativity, most astronomers decided something that strange could exist only on paper. Quasars, on the other hand, were a fortuitous discovery, found through a long process of observation. But they were so strange that even today some astronomers are doggedly trying to avoid placing them at the distance their redshifts indicate. If they lie so very far away, how do we explain their extraordinary energy output? In Alan Lightman's analogy, if the city of Boston represents a normal galaxy in size and energy output, then a quasar is the size of a baseball — but has the energy output of the entire United States!

Today, black hole theory and quasar observations are being combined and, though a lot more work needs to be done, there is a good chance they will interlock satisfactorily. Quasars are small and extremely luminous; black holes are also small, but can be very efficient at producing energy from matter that falls into them. After a long period of controversy, the freak of theory — the black hole — and the freak of observation — the quasar — may now become firmly linked.

Lastly, *theory and observation can continually modify one another until they arrive at a solution.* This process is what happens most of the time in science — it might even be termed "routine" science. The great revolutions, when one particular view of the universe abruptly gives way to another, happen infrequently, though their consequences affect the fundamentals of many parts of science. Thus, the revolutions of Copernicus, Newton, and Einstein are landmarks in astronomy.

But every day, "revolutions" of far lesser scope take place in hundreds of laboratories and universities around the world. Individually, these have little significance; cumulatively, they can change a great deal by creating a new view of the universe gradually.

Unfortunately, it's up to the reader to draw these conclusions. The book itself contains no summary about the relationships outlined here. It is not a comprehensive study of how science works, but more a book of case studies.

But much of this material is fascinating — perhaps because it is controversial. Fred Whipple suggests that a supernova triggered the formation of our solar system. Fred Franklin uses computer simulations to suggest that our solar system is a fluke in a universe of multiple star systems. John Huchra shows how recent observations suggest that the universe may be only eight or 10 billion years old. And in a final chapter on some unanswered astronomical questions, George Field shows why the failure to observe sufficient solar neutrinos could bring about profound changes in our understanding of the universe.

When you finish reading *Revealing the Universe*, you come away with a better, though not complete or balanced, understanding of what is going on at the frontiers of astronomy. For example, the book includes two chapters on the solar corona, but little on the formation and evolution of galaxies.

But this book does examine the workings of a mysterious object few other astronomy books even mention. Undoubtedly the most astonishing object in the universe, it is the human mind — something that can take a few threads of data, couple them to an idea, and weave them into a cosmos.

As Lightman says, "It is a triumph that we, little cosmic ants on our little planet Earth, understand as much as we do about objects on the other side of the universe." The next time the evening news starts making you cynical about the human species, just think of what we have done in astronomy. *Don Lago.*

At the Crossroads of the Earth and the Sky
Gary Urton
248 pages, hardcover, $30
University of Texas Press (1981)

At the Crossroads of the Earth and the Sky introduces the western reader to an alien but rational astronomy. Anyone who is excited by astronomy and cosmology and wants to see what forms they take in another culture will be fascinated by this book.

Gary Urton is a young anthropologist who has investigated contemporary Quechua (Inca) peasant knowledge and concepts of the sky. To fit in with other researchers' work, he sought a community close enough to the Inca capital of Cuzco, Peru, to share the view of the heavens seen from that city. He settled on Misminay, a village 50 kilometers northwest of it.

Urton spent a year and a half in the field, principally in Misminay but also in other communities. He describes the daily life of the Quechua peasants, their ideas about how heavenly bodies relate to the conditions of their Andean mountain valley and their food-producing activities, and shows there is a lot of Incaic astronomy in contemporary Quechua knowledge.

Misminay peasants live by cultivating a variety of crops — maize, wheat, potatoes — and by raising sheep and a few cattle. Men are responsible for the agricultural work, women for herding the livestock. Families usually remain indoors at night — fearing evil spirits outside — but the villagers are familiar with a number of stars, planets, and constellations seen around twilight or dawn.

The astronomy of the Misminay peasants is oriented toward marking the changes of the seasons as they affect agriculture. Because the Indians raise a variety of crops, with different times for planting and harvesting, their astronomy is fairly complex. Misminay astronomy also reflects the general cosmology of the Quechua and some Incaic practices that have been changed to better coincide with the peasant way of life.

For example, Misminay peasants substitute mountain peaks on their horizon for the stone pillars the Inca

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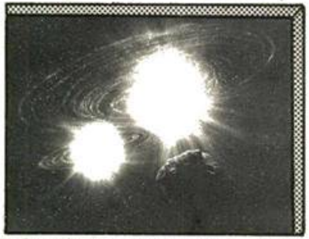

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astronomers used for markers. In addition, certain Catholic festivals on saints' days are celebrated in Misminay because they coincide with important planting or harvesting dates.

To a North American reader, the most unusual feature of Misminay — and Incaic — astronomy is the recognition of clouds of interstellar dust in the Milky Way as "dark-cloud" constellations. The most important such dark-cloud constellation is The Llama, which extends between the Southern Cross and Epsilon Scorpii and lies overhead during summer, the rainy season and therefore the more active farming period. Llama ewes give birth during this season and the constellation includes a baby llama or its umbilicus.

The Quechuas believe that certain constellations and other astronomical phenomena control the procreation of various Andean animals. This is perfectly logical when you consider that the astronomical phenomena are seen during the periods of the year when the animals in fact produce their young.

The equatorial location of Misminay means that the broad sweep of the Milky Way dominates Quechua observations of the night sky. The center of the Galaxy in Sagittarius passes overhead about 10° from the zenith. With the Milky Way so impressive and the south celestial pole lacking a bright star to mark it, these southern hemisphere dwellers naturally use the Milky Way as the base for their sky maps. They call it "The River" and believe that it is the above-Earth branch of the Vilcanota River that flows through the Earth near Misminay and Cuzco.

Around Misminay, footpaths and irrigation canals divide the community into quarters that reflect a division of the sky by the axes of the Milky Way as it passes through the zenith. The Misminay peasants use the intercardinal points — such as northeast and southwest — and not the cardinal directions, for orientation.

This orientation crops up both in the choice of certain mountain peaks for direction markers and in the recognition of a celestial cross which they form by extending one line from Castor in Gemini to the middle of Orion's Belt and another from Procyon in Canis Minor to Beta Tauri.

In the course of the book, the author describes Quechua beliefs about the Sun and Moon, as well as rainbows, halos, and other meteorological phenomena. He relates them to the peasants' experience of rain and drought, plant and animal growth cycles, and similar natural events. Then he shows that the Quechua beliefs are frequently common-sense deductions and — in the case of the linking of planting dates to astronomical phenomena — a sophisticated way of dealing with complex relationships.

Urton doesn't develop Quechua symbolism as fully as he might — he does not go into the importance of mountains and vertical relationships which have been described by other anthropologists — but given the focus of his work on astronomy, the limitations of his discussion are justifiable.

He also candidly admits to some problems that affected his work, such as being unable to talk frankly with Misminay women, and having to identify stars which his informants would not point to — because pointing is impolite in Misminay!

Although it is strongly anthropological in its approach, this is a book that anyone curious about non-European astronomy will find very interesting. *Alice B. Kehoe.*

Introduction to Comets
John C. Brandt and Robert D. Chapman
246 pages, hardcover, $45
Cambridge University Press (1981)

After a brief historical survey of comet studies, the authors explain current comet theory. A short section on "the lay perspective" covers comet lore and "Are comets dangerous?" The book is for those who have had some exposure to mathematics and physics at an undergraduate level.

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The High Road
Ben Bova
289 pages, hardcover, $11.95
Houghton, Mifflin (1982)

Bova, a well-known science fiction writer, explores the technologies he thinks necessary to assure human survival. The book's argument is that we must develop space industry and colonies, and that our only hope is a greatly expanded space program.

The Nature of Matter
J. H. Mulvey, ed.
202 pages, hardcover, $15.95
Oxford University Press (1982)

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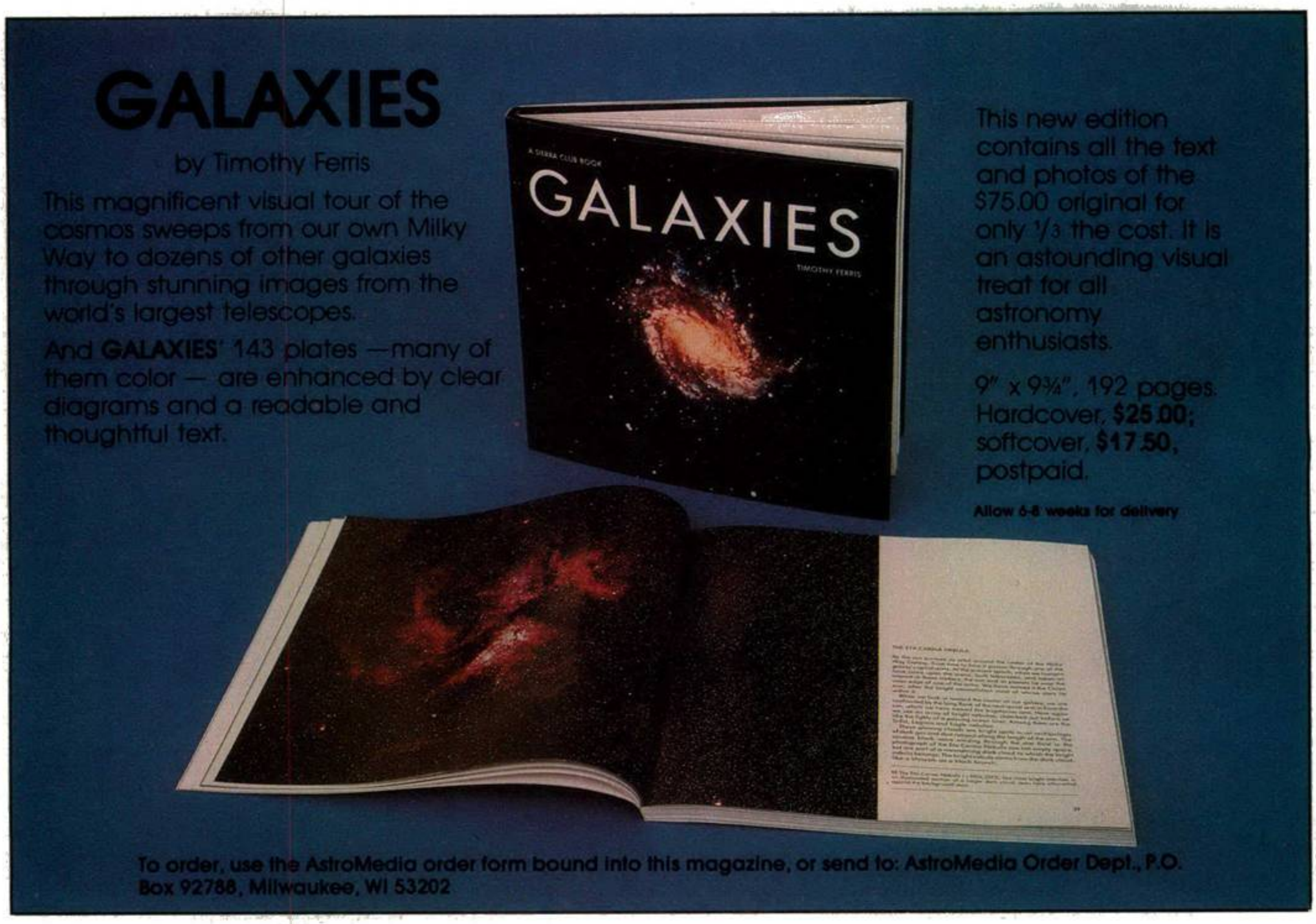

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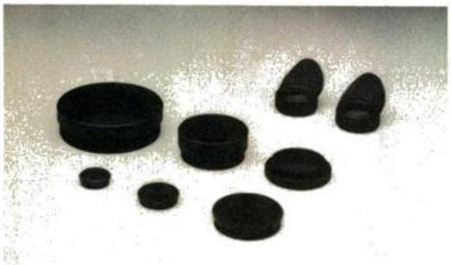

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Never look at the sun in any telescope without a solar filter! Eye damage would result. Celestron solar filters are totally safe for viewing and photography. Don't try to project the sun's image without a filter, if you try this old technique with a Celestron you run the risk of heating the baffle tube or optical glass and causing breakage of the optics. The sun is in an active period now, be prepared to view our nearest star in comfort and complete safety with solar filters that are now in stock from Celestron.

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ASTRONEWS

Starlight Detected Around Quasar

For years, astronomers have suspected that quasars are immense black holes embedded in the centers of galaxies. Now, two Caltech astronomers have confirmed this suspicion by obtaining the first evidence for a galaxy surrounding a quasar.

The finding ties up a loose end in astronomy, according to Todd Boroson and J.B. Oke, the two astronomers. The discovery is a crucial link in relating quasars to active galactic nuclei and to normal galaxies, and also marks the first step toward understanding what kinds of galaxies harbor quasars.

The object of the study was the quasar 3C 48, about five billion light-years from Earth. It is a relatively nearby quasar surrounded by a faint, wispy nebulosity. Astronomers have made observations, but had not detected light that would hint at stars in the nebulosity — only emission lines that indicated the presence of hot gas.

The key to this new success is a double spectrograph which divides light from the quasar into two beams — one blue and violet, and other yellow and red. The light from each beam is then separated into its constituent colors and is imaged onto light-sensitve detectors.

The discovery is a spin-off benefit from NASA's Space Telescope — even before the instrument has left the ground. The CCD array used in the camera was a reject from the Space Telescope project because of a flaw, but it was well suited to the Caltech astronomers' needs.

Using the double spectrograph, the astronomers observed 3C48 on November 4 and December 16, 1981. On each night, the camera gathered light from the quasar for eight minutes and from its faint surrounding nebulosity for 50 minutes. The astronomers then used a computer to correct for sky luminosity and to subtract quasar light from nebulosity light. The resulting spectrum showed hydrogen and calcium absorption lines characteristic of galaxies with young hot stars.

"This finding was surprising because we assumed that galaxies would be composed mainly of cooler, late-type stars," said Boroson. "If this is a common phenomenon among galaxies surrounding quasars, it may mean that shocks emanating from quasars trigger bursts of star formation.

"We also expected that galaxies surrounding quasars would be giant elliptical galaxies, but the one we observed appears to contain too many young stars for such a galaxy, so it may be a spiral."

Violent Ejection Spews from Star

Astronomers at NASA's Goddard Space Flight Center, the University of Maryland, and Lick Observatory have detected a violent ejection or jet from a star close to the Sun.

Most of the jets that astronomers detect are from the center of active galaxies or quasars. But this observation reveals an extraordinary jet structure in the binary star system R Aquarii. In contrast to SS 433, the only other star known to have jet structure in our galaxy, R Aquarii is much closer to the Sun — only 750 light-years away.

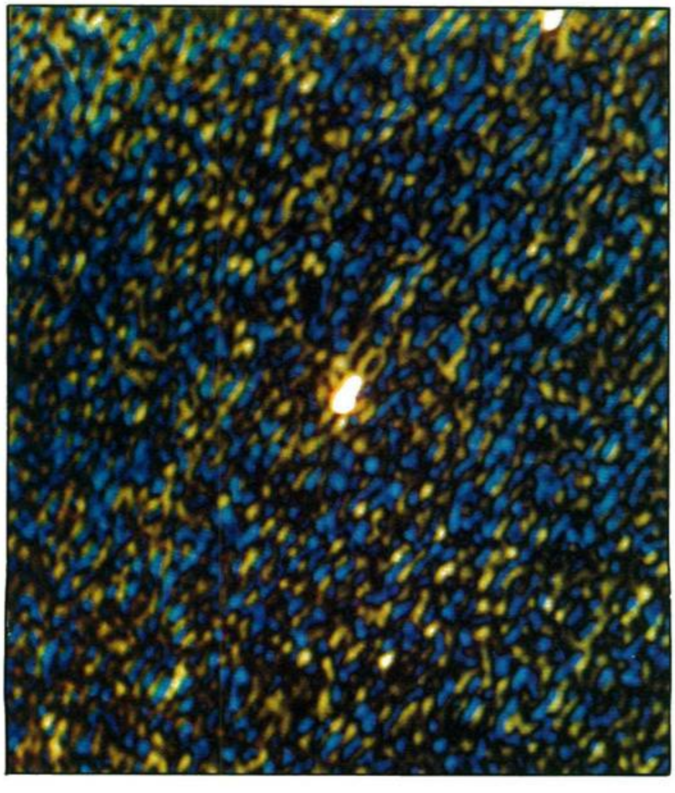
Andrew Michalitsianos of Goddard describes the jet — detected with the Very Large Array radio telescope located at Socorro, New Mexico — as extended and well collimated, with a structure similar to that seen in visible light by George Herbig with the 120-inch telescope at Lick Observatory. The jet is 20 times the length of our solar system, and the material in it is moving at 1,080 miles per second.

"We believe that a jet in R Aquarii is evidence for an accretion disk of material captured by an unseen stellar companion of the cool red variable R Aquarii," said Minas Katafos, an astronomer on the project. The accretion disk, estimated at 25 times the Earth-Sun distance in diameter would be just observable with the Space Telescope.

SS 433 is 20 times farther from the Sun than R Aquarii and is difficult to observe. Therefore, R Aquarii may be the only object that astronomers can use to directly examine the formation of a jet structure.

Radio observations of the jet structure by Robert Sopka of the University of Maryland showed a previously unknown radio source. If associated with R Aquarii, it may be material previously ejected during an outburst measured in the early 1930s.

A Very Large Array image of the R Aquarii jet. NASA photo.



A Very Fast Pulsar

Scientists at NASA's Marshall Space Flight Center in Huntsville, Alabama, have discovered the third fastest pulsar.

A pulsar is a neutron star that appears to turn "on" and "off" at intervals consistent with its rate of rotation. Neutron stars are usually formed when the collapse of a normal star — such as our Sun — reduces a star's matter to neutrons.

"The pulse rate of this pulsar in the Large Magellanic Cloud is once every 69 thousandths of a second," according to Martin Weisskopf of the Marshall Center's Space Science Laboratory. "Only two are faster than that — the Crab Pulsar which pulses once every 33 thousandths of a second, and the Binary Radio Pulsar which pulses once every 59 thousandths of a second."

Weisskopf, Ronald Elsner and Dennis Leahy made the discovery in conjunction with Gerald Skinner of the University of Birmingham, England.

"Skinner made some initial observations of an X-ray source in this system from data obtained with the HEAO-1 satellite and requested further study with the Monitor Proportional Counter aboard HEAO-2," said Weisskopf.

"The Monitor Proportional Counter gave us the capability to measure the X-ray pulsations more accurately," said Skinner. "Our data from HEAO-1 told us only that there was something interesting to study in that region of the system."

Data from HEAO-2 showed the extremely fast pulsation from an X-ray source to be that of a pulsar. Analysis now indicates that the pulsar's size is approximately 10 miles in diameter. This is extremely small, but the object still has the same mass as our Sun, which is 430,000 miles in diameter.

The new pulsar's magnetic field is similar in shape to a bar magnet. Rotation causes the pulses when the poles of the pulsar point in Earth's direction every 69 thousandths of a second.

Additionally, the pulsar "orbits" around a normal, or primary star, much as a planet rotates around its sun. The orbit takes 16.6 days.

"We surmise there were two stars in the system and one has collapsed. Normally this would cause the disintegration of both,

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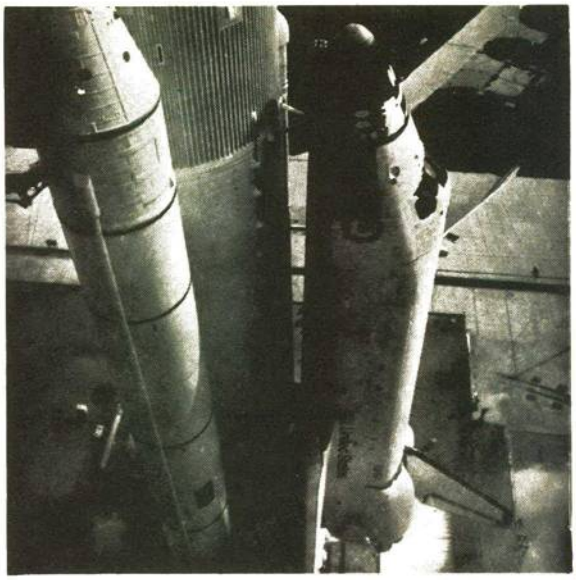

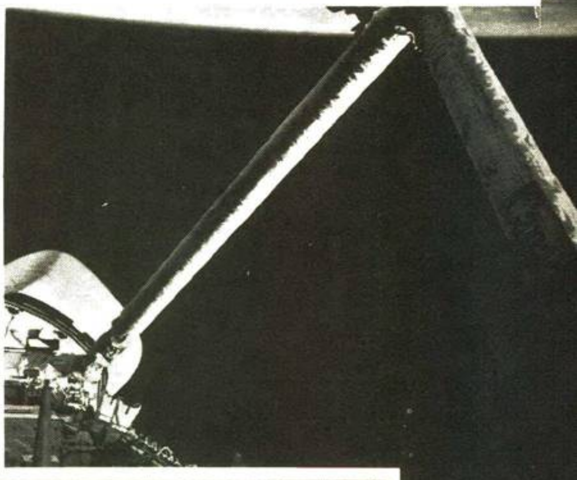

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but the system was organized well enough to adjust to the new circumstances and the pulsar began orbiting the remaining star," said Weisskopf.

"Our first opportunity to study the area again, and confirm our data, will be with the European satellite, EXOSAT, proposed for launch later this year," said Skinner. "This satellite will have two telescopes similar to those on HEAO-2, but smaller, and a Monitor Proportional Counter larger than that aboard HEAO-2. I hope we can get a really good constant study for the entire 16.6 day rotation cycle."

"Much of our data indicates this system is out of the ordinary, which is why we're trying to find out how it all works, and why it is different," concluded Weisskopf.

Optics Experts Confer on 300-inch Scope

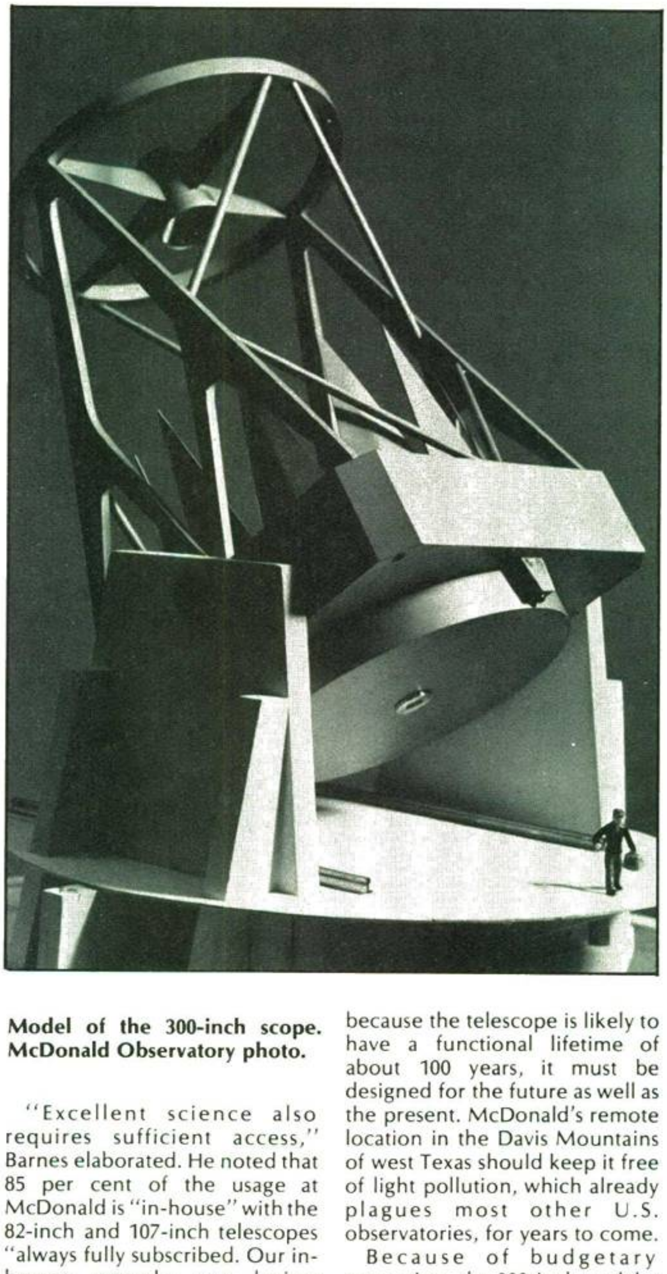
The optical design for the world's largest single-mirror telescope came under scrutiny earlier this year as fifteen experts in astronomical optics gathered at the University of Texas at Austin for a three-day conference on the 300-inch telescope proposed for UT's McDonald Observatory.

Harlan Smith, director of the observatory, told the optics experts that the 300-inch project is "in high gear" with an active campaign to raise the $50 million needed to build a telescope with a primary mirror diameter equal to the height of a two-story building.

Tom Barnes, assistant director of McDonald Observatory, summed up reasons for building the 300-inch reflector in one simple statement: "If you want to do excellent science, you need excellent facilities."

McDonald's 82-inch scope, its first, was the second largest in the world when it was built in the 1930s. Today its ranking has fallen to about 27th place. *Similarly, the* observatory's 107-inch telescope, the third largest when it was completed in the 1960s, is now 13th in size.

Barnes said that McDonald, nevertheless, has been able to maintain its reputation as a world-class observatory through its advances in instrumentation — primarily in spectrometry detectors, photometry and computer controls.



Model of the 300-inch scope. McDonald Observatory photo.

"Excellent science also requires sufficient access," Barnes elaborated. He noted that 85 per cent of the usage at McDonald is "in-house" with the 82-inch and 107-inch telescopes "always fully subscribed. Our in-house people are being squeezed out of telescope time."

One of the primary purposes of the proposed telescope is to permit the continuation of the observatory's major programs in high-resolution spectrometry (stellar and planetary atmospheres), moderate and low resolution spectrometry (quasars and galaxies) and photometry (cataclysmic variables and galaxies). Those programs require telescopes with good imagery on the axis and large aperture.

Such requirements have been taken into consideration in the design of the 300-inch, but because the telescope is likely to have a functional lifetime of about 100 years, it must be designed for the future as well as the present. McDonald's remote location in the Davis Mountains of west Texas should keep it free of light pollution, which already plagues most other U.S. observatories, for years to come.

Because of budgetary constraints, the 300-inch can't be all things to all astronomers. Compromises in design will be made, and the telescope will be an extension of existing technology more than an exercise in innovation.

But the scope's major component — the 300-inch primary mirror — does represent a revolutionary design. If the 300-inch were be to built like the Russian 240-inch, now the world's largest telescope, or the 200-inch at Mount Palomar in California, the largest in the United States, its mirror would have to be four to five feet thick and weigh 100 tons. Instead, the 300-inch mirror will be super-thin by telescope standards — only four to five inches thick — and will weigh about 10 tons.

The mounting selected for the telescope is not equatorial, but altitude-azimuth. The design also calls for an extremely short focal ratio, f/2.0, making the telescope only twice as long as it is wide. That will yield not only a less costly telescope, but will also result in a cheaper dome no larger than the one that houses the observatory's 82-inch telescope.

JPL Director to Step Down

Bruce Murray will step down later this year as Director of the Jet Propulsion Laboratory. A search for his successor is underway.

Marvin L. Goldberger, President of the California Institute of Technology which operates JPL for NASA, recently announced Murray's planned resignation and said, "Bruce Murray has made an enormous contribution to space science and the exploration of the solar system, both as an academician and as an administrator. His inspiring leadership at JPL has served well the Laboratory, Caltech and the nation.

"We are deeply indebted to Dr. Murray for his avid advocacy for a strong and consistent U.S. space program and for his outstanding leadership of JPL. I am personally saddened at losing him as JPL's Director but I can understand his desire to evolve professionally by moving toward a new phase in his career."

In his State of the Lab Address, Murray, who became JPL Director in 1976, commented: "Now that JPL is on the threshold of a new era extending through the '80s and beyond, it is important that the JPL Director commit himself to leading its programs through the remainder of this decade.

"Last year, as I began to lead JPL into its necessary transition, I also began to realize that the proper time for the transition to a new Director would be approaching. Even while Voyager 2 was triumphantly passing Saturn last August, my wife, Suzanne, and I were making some serious new personal plans for later this year. We have some long-overdue travel we wish to start. And I have some serious *writing that I* am

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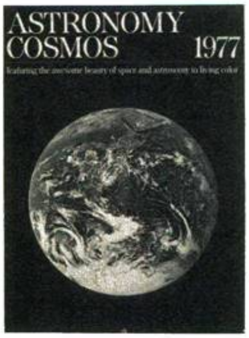
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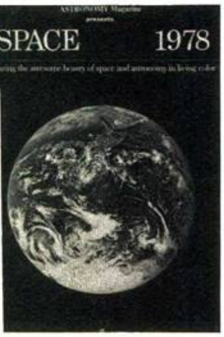

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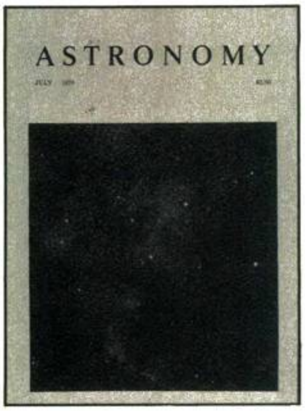

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anxious to get started, once I'm free of the demands of being Director."

Murray said recent events affecting the future of JPL make this the right time for a change in Laboratory leadership. He said although there were setbacks last year in some space exploration and energy activities, JPL is in the process of strengthening its overall posture as a high technology center by expanding its work in selected areas for the Department of Defense.

The search committee for Murray's successor includes John Braun and Simon Ramo, CalTech trustees; Paul Dimotakis and Peter Goldreich, CalTech faculty; David Morrison, CalTech Vice President; and Fred Felberg and Gene Giberson of JPL's Executive Council.

HEAOs' Mission Over

NASA's trio of HEAO satellites — designed to study high energy radiation including X-rays and cosmic rays — opened new worlds for astronomers with their launches in the late 1970s. Now the HEAO mission is over. HEAO-1 re-entered the Earth's atmosphere and was destroyed in 1979. HEAO-3 experienced a similar fate last December, and HEAO-2 completed the circuit early this year when it too burned up in the Earth's atmosphere.

HEAO stands for High Energy Astronomical Observatory — and the HEAOs were just that: observatories. Each of the three had a specialized function it alone was designed to carry out.

HEAO-1 scanned the heavens in a general survey and mapped X-ray sources throughout the celestial sphere. The initial survey was completed in February 1978, but the satellite studied the skies until its control gas was exhausted in January 1979. During that 17-month study, HEAO-1 increased the number of known X-ray sources from 350 to 1,500. It also discovered a new black hole candidate and indicated the possible existence of a universal hot plasma that might constitute a major fraction of the universe's mass.

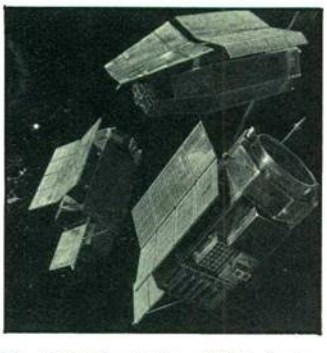
Additionally, HEAO-1 discovered a superhot halo of gas, 1200 light-years in diameter, surrounding the Northern Cross. The halo, or "superbubble," is 6,000 light-years from Earth in the next spiral arm of our Galaxy. Its discovery has formed the basis of a new theory of star formation.

The second high energy observatory, HEAO-2, focused on specific observation guided in part by the general survey of its predecessor. Nicknamed the "Einstein observatory" because its launch date was approximately that of the scientist's 100th birthday, HEAO-2 was rocketed into orbit in November 1978. Although it was designed for a mission life of twelve months, the observatory operated for nearly two and a half years.

Carrying the largest X-ray telescope ever built and a variety of sensitive astronomy instruments, HEAO-2 conducted the detailed imaging and spectroscopic observations of approximately 300 bright X-ray sources and discovered thousands of new faint X-ray sources, showing almost every type of star in the Galaxy to have an X-ray-emitting atmosphere.

HEAO-2 obtained the first X-ray photographs of supernova remnants, pulsars, star clusters, galactic diffuse X-ray sources, bright sources in other galaxies, and of diffuse emission from clusters of galaxies. It also detected hundreds of active galaxies and quasars, some of which may be the most distant objects ever observed at any wavelength. The Einstein observations have already had an impact upon many fields of astronomy.

The final observatory in the HEAO series was launched in September 1979. Unlike its predecessors which were designed to study X-rays, HEAO-3 furthered knowledge about cosmic-ray particles and gamma-ray photons — the two highest energy radiations in the universe. Through the study of cosmic rays — the nuclei of elements and the most energetic particles we know — HEAO-3 measured the relative abundance of elements in the Galaxy. The observatory found significant differences between the amounts of certain nuclei in the galaxy and the same elements in the solar system.


The HEAO satellites. TRW photo.

HEAO-3 made precise, high-resolution measurements of gamma-ray "line emission" from solar flares and from positive and negative electrons combining near the galactic center. These and other data will further our understanding of the strength and extent of interstellar magnetic fields, the distribution of interstellar matter, and the stellar nucleosynthesis process which has created the heavy elements. Scientists say that it will take years to complete analyses of the massive amount of data returned from these three very successful orbiting observatories.

Finding Planets

Do unknown planets orbit other stars? It may soon be possible to detect planets orbiting nearby stars, claims David Black of the NASA Ames Research Center, who believes that scientists can conduct a comprehensive search relatively soon — and at a modest cost.

In the Joint Annual Meeting of the American Physical Society and the American Association of Physics Teachers, Black contended that recent advances in astrometric and spectroscopic systems will make it possible to find Jupiter-sized planets revolving around nearby stars. The first step in that direction is a comprehensive spectroscopic observing program using a land-based telescope. Such a program could be started in the next two to three years, according to Black, and at the modest cost of $10 million.

On the astrometric side, the Space Telescope will alleviate problems caused by the Earth's turbulent atmosphere — the bane of ground-based astrometric detection. The potential for this telescope is vast. Not only could it find Earth-sized planets accompanying close stars, it could also find Jupiter-sized planets revolving around stars more than 100 light-years away.

One mode of finding planetary companions of nearby stars is to detect the radiation that they emit — both visible and infrared. A planet's atmosphere reflects much of the visible light that falls on it. But detecting a planet by visible light is difficult because nearby stars would wash out its faint light. According to Black, this is like "looking at a billion-watt searchlight located a mile away and trying to see a one-watt penlight attached to the side of it."

The amount of infrared radiation emitted by the planet and a nearby star would not be as great, and would have less chance of "washing out" a measurement. But while this approach appears more effective than searching for visible light, present day infrared detectors are not sensitive enough to detect a planet.

So direct detection of other planets — either in the visible or the infrared — seems improbable; scientists have to use more indirect methods. We know that the orbit of a planet disturbs the path of its central star. As the planet rotates, the star itself revolves around the center of mass of the planetary system. When a star moves across the sky, it moves in a straight path if no planets disturb it. But if planets orbit it, the path will be altered. These alterations can be detected by astrometric and spectroscopic means.

The Space Telescope will detect visible radiation and, thus, it has only limited chance of finding other planetary systems. It will not provide the comprehensive search that Black thinks is necessary — and there are no plans for the construction of a space-based infrared telescope. Black believes that the capacity for detecting planetary companions of nearby stars is within our means, but lack of money holds us back. *John Ripka.*

Dim Your Lights

Because light pollution is drowning out the faint light sources astronomers study (see "Bright Lights Ahead," ASTRONOMY, April 1982), observatories around Tucson have banded together to approach civic leaders and seek assistance in preserving the prime quality of the night skies in their area.

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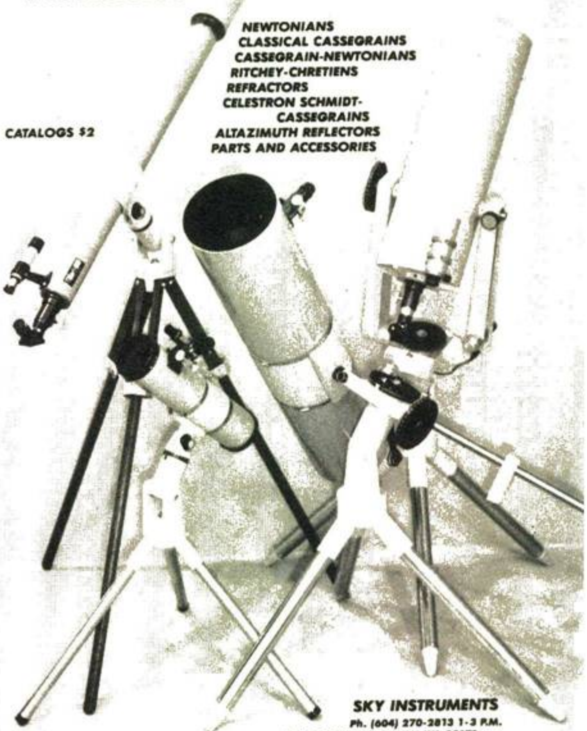

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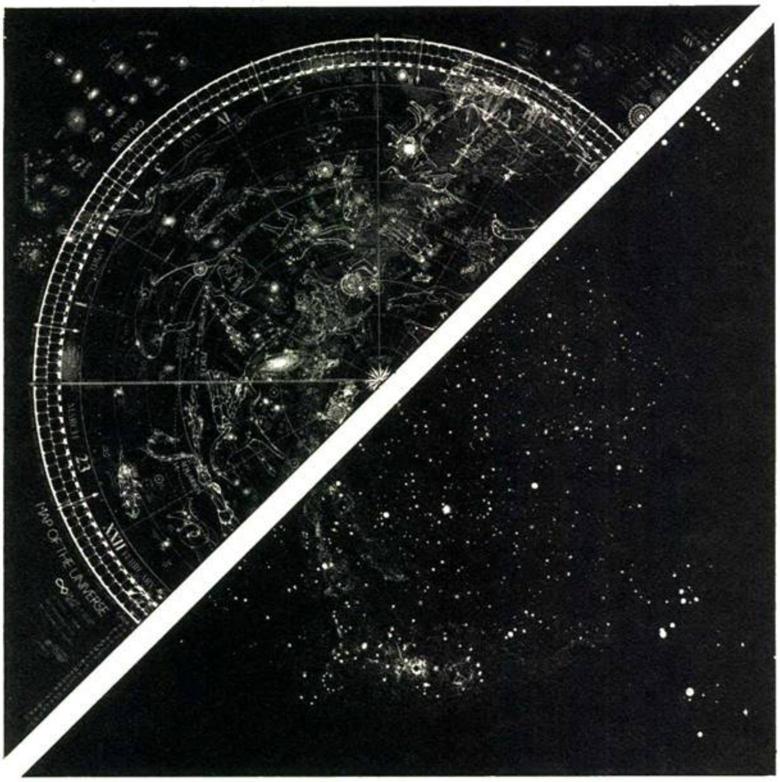

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ASTRO NEWS

(MMTO), operated jointly by the Smithsonian Institution and the University of Arizona at its Mt. Hopkins location, 40 miles south of Tucson; and the 4-meter (158-inch) Mayall telescope of the Kitt Peak National Observatory, 40 air miles southwest of Tucson. Other major telescopes operate in and around Tucson, and the world's greatest concentration of optical telescopes is at Kitt Peak.

Early in 1981, both the city of Tucson and Pima County passed revised outdoor lighting ordinances more stringent than original statutes of this type enacted in 1972. But to effectively preserve the night skies of southern Arizona, the astronomers are encouraging municipalities and counties to pass ordinances which require shields or filters on outdoor municipal lights. They are also suggesting the use of low pressure sodium vapor lamps, a light source easy for astronomers to filter out. This expanded effort started in August 1981, when Kitt Peak retained illuminating engineer William Robinson to contact municipal and county leaders all over southern Arizona.

Early efforts were directed east of Pima County to Graham County and its major towns of Safford and Thatcher. Mt. Graham, at 11,000 ft., is one of several sites being considered for the world's largest telescope — Kitt Peak's advanced-design 600-inch telescope that is now on the drawing boards.

Civic officials cooperated with the astronomers from the start, and passed ordinances in Graham County and the towns of Safford and Thatcher. Officials have been pleased to help protect a worthy endeavor, and they've also realized considerable energy savings for their communities by converting to more efficient lighting systems.

Ted Wolverton, City Manager of Willcox in Cochise County southeast of Tucson, took the initiative in approaching Robinson and expressed his interest in getting an ordinance passed. Wolverton understood the importance of southern Arizona to astronomy; he is an amateur astronomer himself. "The thing that sparked our community leaders was learning of the possibility of the world's largest telescope being built within eyeshot of Willcox," remarked Wolverton. "Passing these ordinances throughout Graham and Cochise Counties will improve the chances that this telescope may be placed here." Early this year, Willcox and Cochise County passed outdoor lighting ordinances.

Mutual action by the mayors of Nogales, Arizona; and Nogales, Sonora, Mexico added to the astronomers' success. This cooperation was especially significant because of the international aspect. Both cities are installing new, more efficient lights.

Robinson, with assistance from Dan Brocious of Whipple Observatory, Nicholas Wool of the University of Arizona's Steward Observatory, and several KPNO staff members, is working in Santa Cruz County to the south — home of the Whipple Observatory and the MMTO — and in Pinal County to the north. Officials are currently reviewing the information recently presented to them. After consolidating southern Arizona, these astronomers and engineers will turn their attention to the major population center of Arizona — Maricopa County, with Phoenix and its suburbs.

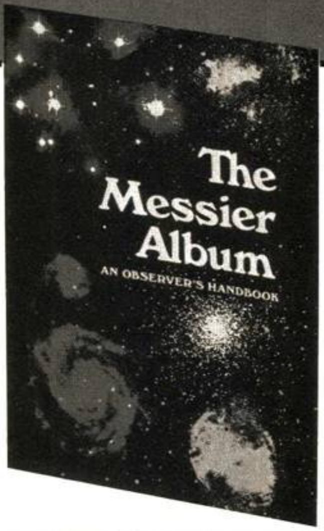
Kitt Peak Astronomer David Crawford has for years been active locally and nationally in efforts to reduce light pollution; he is also the chairman of the American Astronomical Society's Committee on light pollution. Crawford expressed concern of professional and amateur astronomers alike in this way, "We don't want to see southern Arizona go the way of southern California, where we're losing the maximum usefulness of several major observatories because of unrestricted growth in outdoor night lighting."

Robinson shares this concern and adds, "It's ironic that, as successful as we have been in our recent efforts to reduce light pollution, future work is threatened by a lack of funding. We need support from interested private sources. Kitt Peak's budget has suffered several cuts recently, and it's hard to support programs where payoff is very important but long term, especially when immediate needs are suffering. The money we were able to squeeze from the Kitt Peak budget to get this project started is running out."

ASTRO CALENDAR

June 26-July 1.	**93rd Annual Meeting of the Astronomical Society of the Pacific.** University of California, San Diego — La Jolla, California. Send SASE to: San Diego Meeting, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.
July 16-18.	**Connecticut River Valley Astronomers' Conjunction.** Northfield Mountain Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Rd., Springfield, MA 01118
July 16-19.	**International Student Space Conference,** sponsored by Students for the Exploration and Development of Space. Washington, D.C. Contact: SEDS Conference, 800 21st Street, P.O. Box 24, Washington, DC 20052.
July 16-24.	**National Spaceweek.** Needs local organizers. Contact: Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77058.
July 16-24.	**Florida Spaceweek '82.** Various cities. Contact: Florida Spaceweek Committee, 993 Macco Road, Cocoa, FL 32922.
July 18-August 8.	**International Workshop for Amateur Astronomers** (I.W.A.A.). Havelte, The Netherlands. Contact: Niels van Weersen, Sand-Ambachstraat 17, 2691 BL 's Gravenzande, The Netherlands.
July 21.	**24th Annual Summer Science Program in Astronomy.** Ojai, California. Contact: Roger D. Klauscer, Thacher School, Ojai, CA 93023.
July 21-24.	**ALCON '82** — national convention of the Astronomical League including ALPO, IAPPP, IOTA and National Deep Sky Observers annual meetings. Peoria, Illinois. Contact: ALCON '82, P.O. Box 5203, Peoria, IL 61601.
August 11-13.	**IAPPP Springfield Meeting.** Hartness House, Springfield, Vermont. Contact: R.C. Wolpert, 144 Neptune Ave., N. Babylon, NY 11704.
August 14-17.	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.
August 17-26.	**XVIII General Assembly of the International Astronomical Union** (professional meeting). University of Patras, Greece. Contact: Organizing Committee, General Assembly IAU, University of Patras, Patras, Greece.
August 27-29.	**Western Amateur Astronomers (WAA) 1982 Convention,** "Focus on Astronomy." Contact: Ames Research Center, Moffett Field, CA 94035.
Sept. 24-26.	**AstroFest.** Chicago Astronomical Society telescope fair and conference. Kankakee, Illinois. Contact: AstroFest, P.O. Box 596, Tinley Park, IL 60477.

ASTRONOMY
Bookshelf



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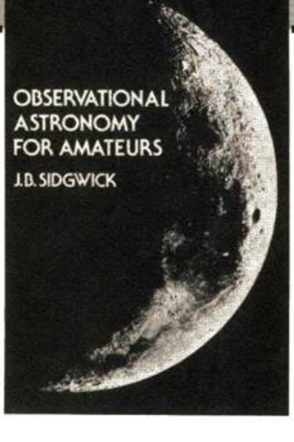

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ВЕНЕРА ОТКРЫВАЕТ ТАЙНЫ ВЕНЕРЫ

REVEALING THE VENUSIAN SECRETS

BY SAM S. MIMS

No special flyers or posters advertised the final talk in the session on "Planetary Interiors and Venus"; they weren't needed. And though the program listed the talk as "Tentative," it seemed as if everyone at NASA's 13th Lunar and Planetary Science Conference, held at the Johnson Space Center in Houston, was in the room, waiting eagerly to hear "New Venera Results" by V.L. Barsukov.

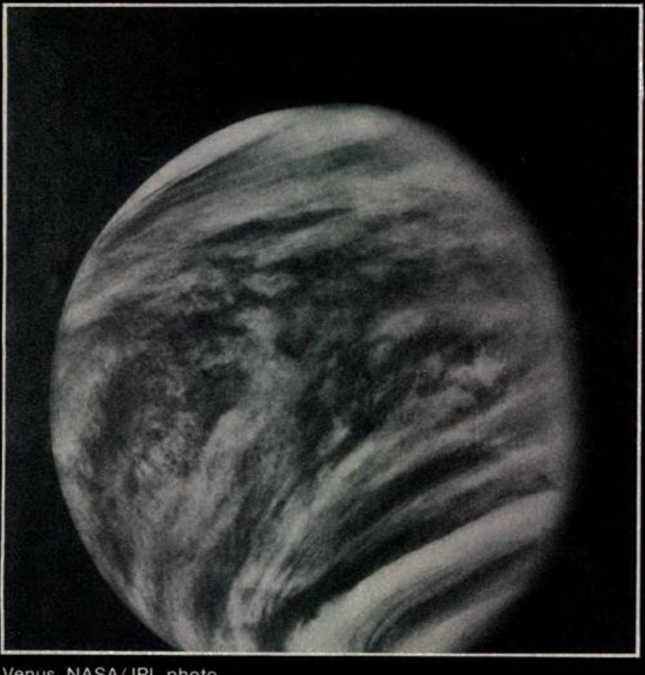
No one minded the awkwardness of having a translator, or the inconvenience of the speaker exceeding his 15-minute limit and almost running through the entire lunch break. Instead, an air of excitement stirred the room as the Soviets revealed to the world the results of their Venera 13 and 14 landings and gave out just what the planetary scientists were thirsting for — detailed reports of soil composition, rock formations, and atmospheric conditions on Venus.

While Veneras 8, 9, and 10, and the U.S. Pioneer Venus craft primarily studied the atmosphere on their descent to the surface, Veneras 13 and 14 were the front line of a new generation of landers. They were designed to study surface and internal compositions, and the atmosphere through samples and detailed on-site analysis — and they had to function despite Venus' hostile climate. Both craft passed the test. Venera 13 transmitted for 127 minutes despite atmospheric pressures from 90 to 0.05 those on Earth and temperatures from 480°C to 30°C; Venera 14 signaled for 57 minutes.

The scientific packages on these craft were considerably more advanced than those on previous missions. New television cameras allowed higher resolution of surface features, and cut transmission times in half. And they imaged the landscape through red, green, and blue filters, giving earthlings the first color views of the venusian surface. Two cameras on each lander pointed in opposite directions and swept over a full panorama from each landing site. The results were amazing.

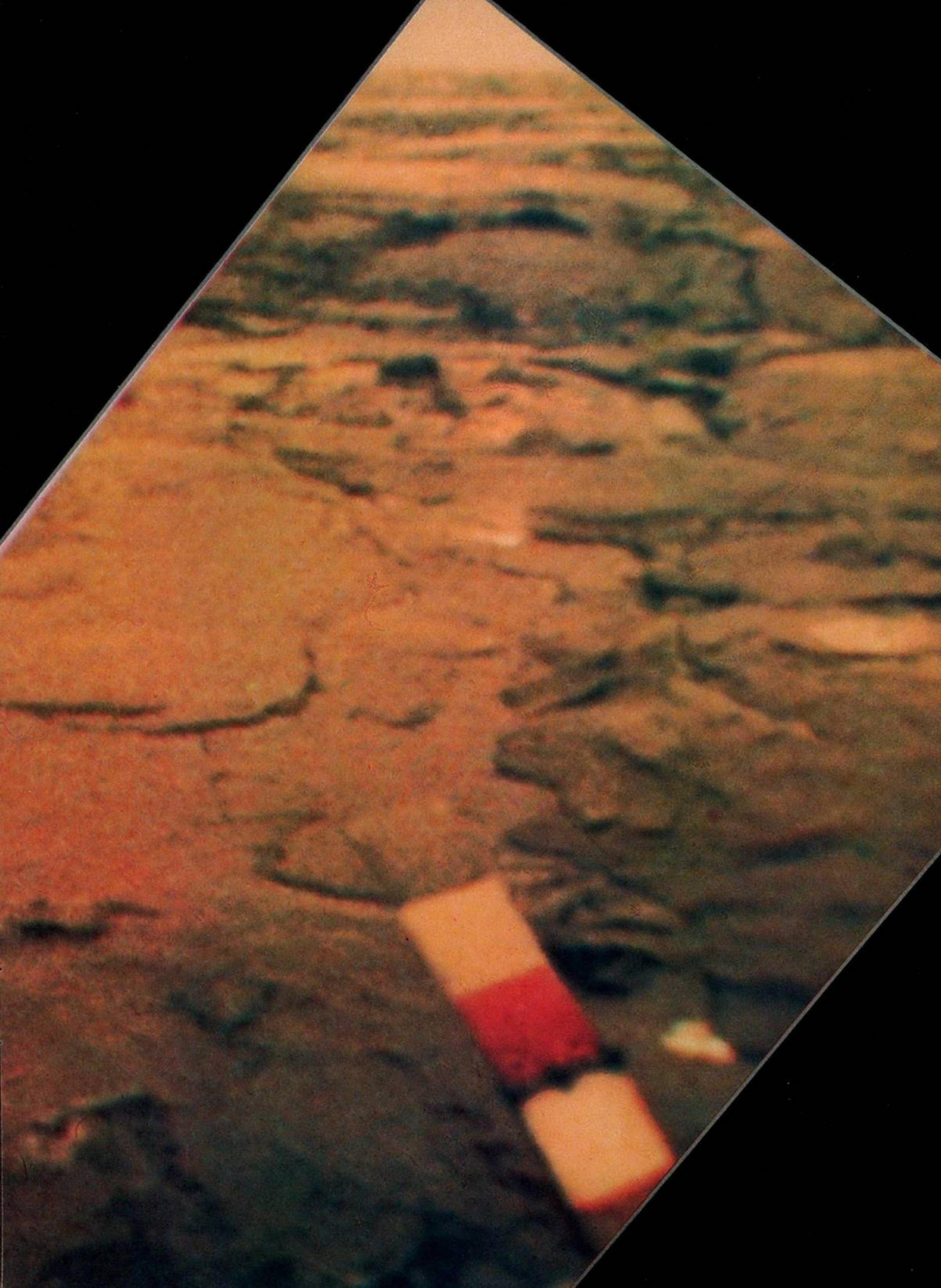
On March 1, Venera 13 landed east of Phoebe Regio, an uplifted area near the venusian equator. Its photos showed a rocky plain with small rock formations, and a fine dust which had settled in cracks in the rocks. The cameras scanned details of just a few millimeters, in comparison to the centimeter resolution of the earlier landers. The spectrophotometer registered a cloud of dust raised from the soft ground by the landing. The rocks at the Phoebe landing site are predominantly sharp; the area resembles lava flows which have been exposed to considerable wind erosion. The atmosphere was transparent enough to reveal details all the way to the horizon.

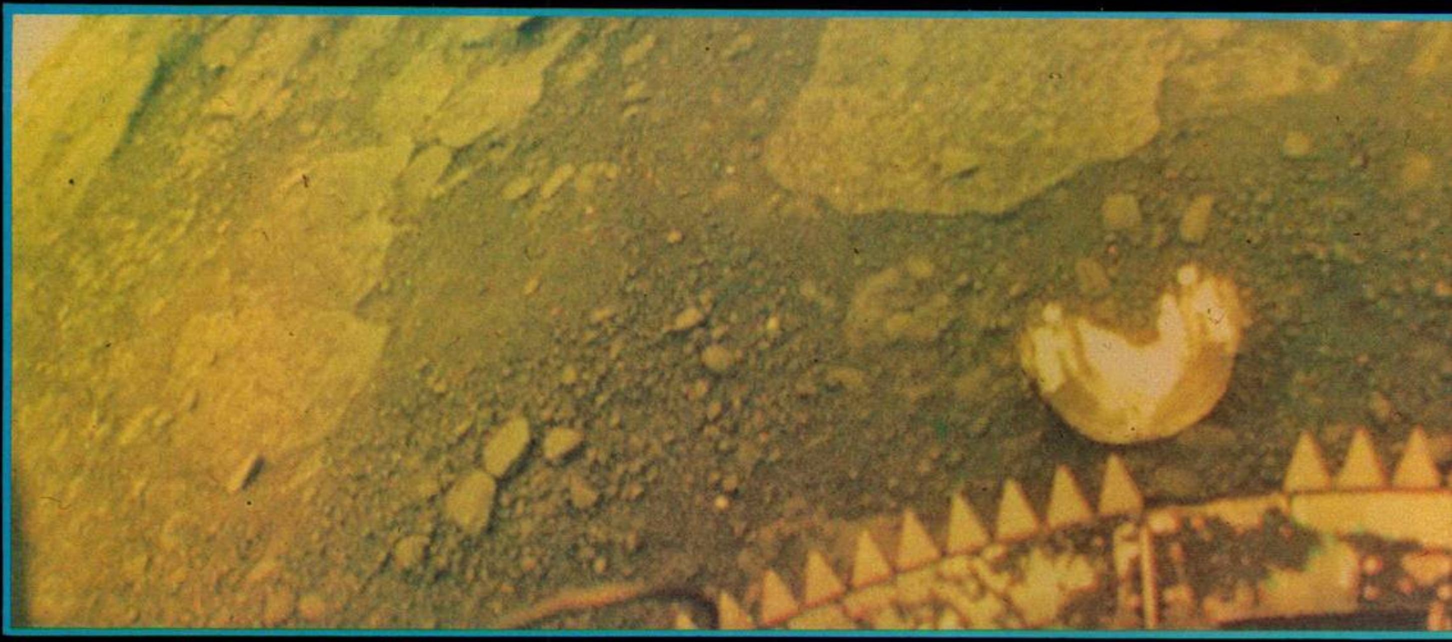
Venera 14 touched down on March 5 south of Beta Regio near the border of a valley; the view from there was astounding. Over an even, rocky plain, formations of layered rocks, reminiscent of terrestrial sedimentary



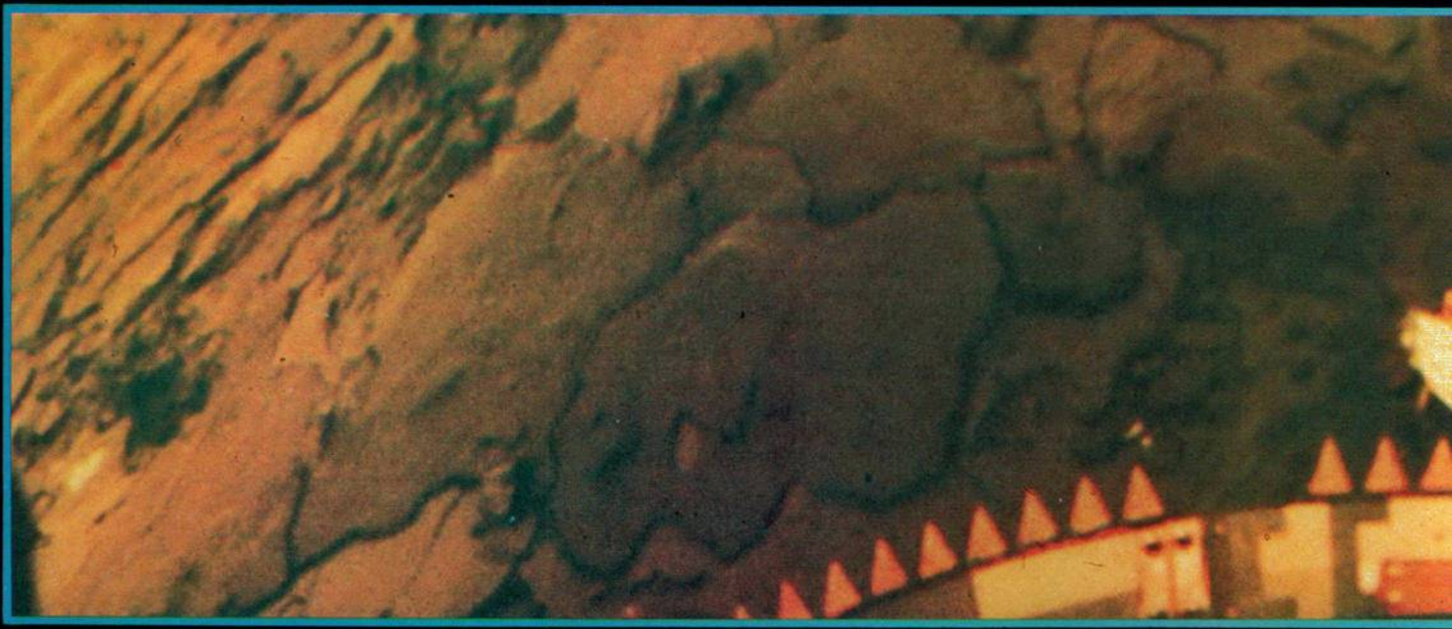
Venus. NASA/JPL photo

The Venera 14 landing site is hot, desolate, and rocky. Repeated lava flows probably formed these layered rocks. The orange-tinted sky of this furnace-like planet shows above the horizon at the top of the photo. Photos Tass from Sovfoto.





Sharp, broken rocks, possibly originating from lava flows that have been exposed to severe wind or chemical erosion, lie scattered about the Venera 13 landing site east of Phoebe Regio. Tass from Sovfoto.



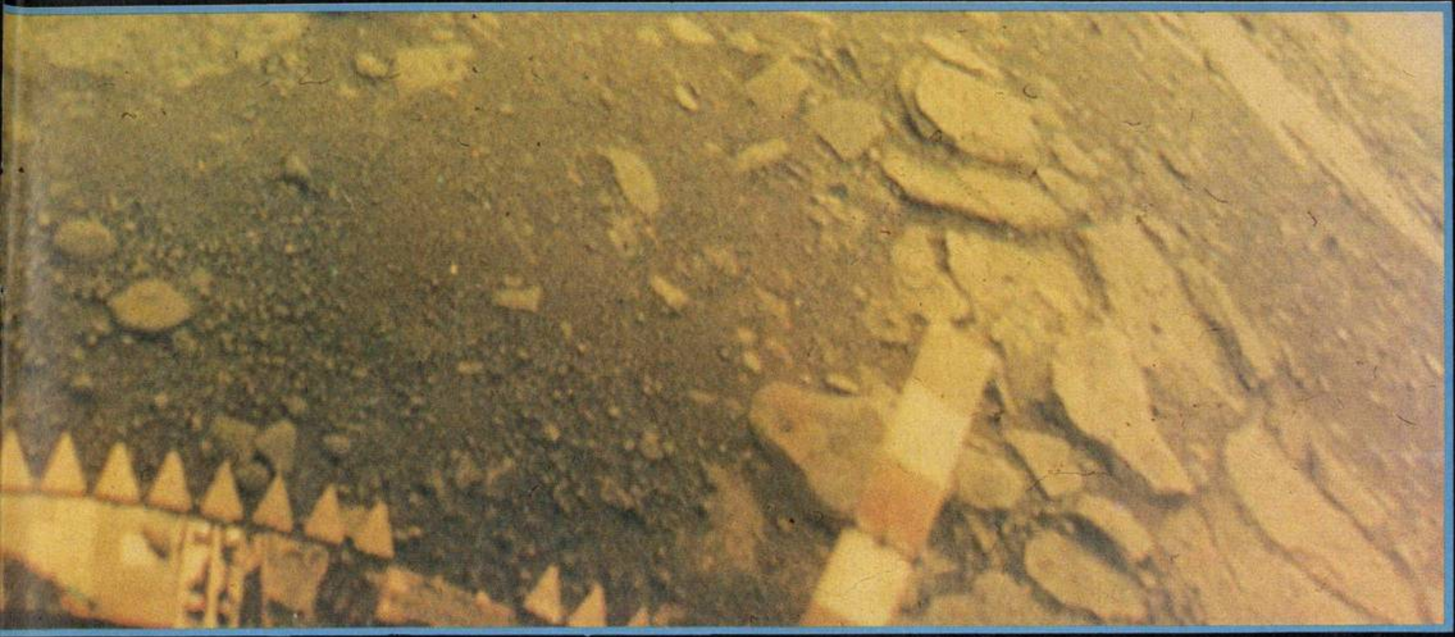
deposits, swept all the way to the horizon. Yet the material is almost certainly layers of volcanic deposits, piled on top of one another. Some photographs showed what looked like explosive volcanic ejecta, probably from nearby Beta Regio. Most scientists think this is a volcanic feature; when Veneras 9 and 10 landed there in 1975, they found radioactivity levels suggestive of volcanic rocks.

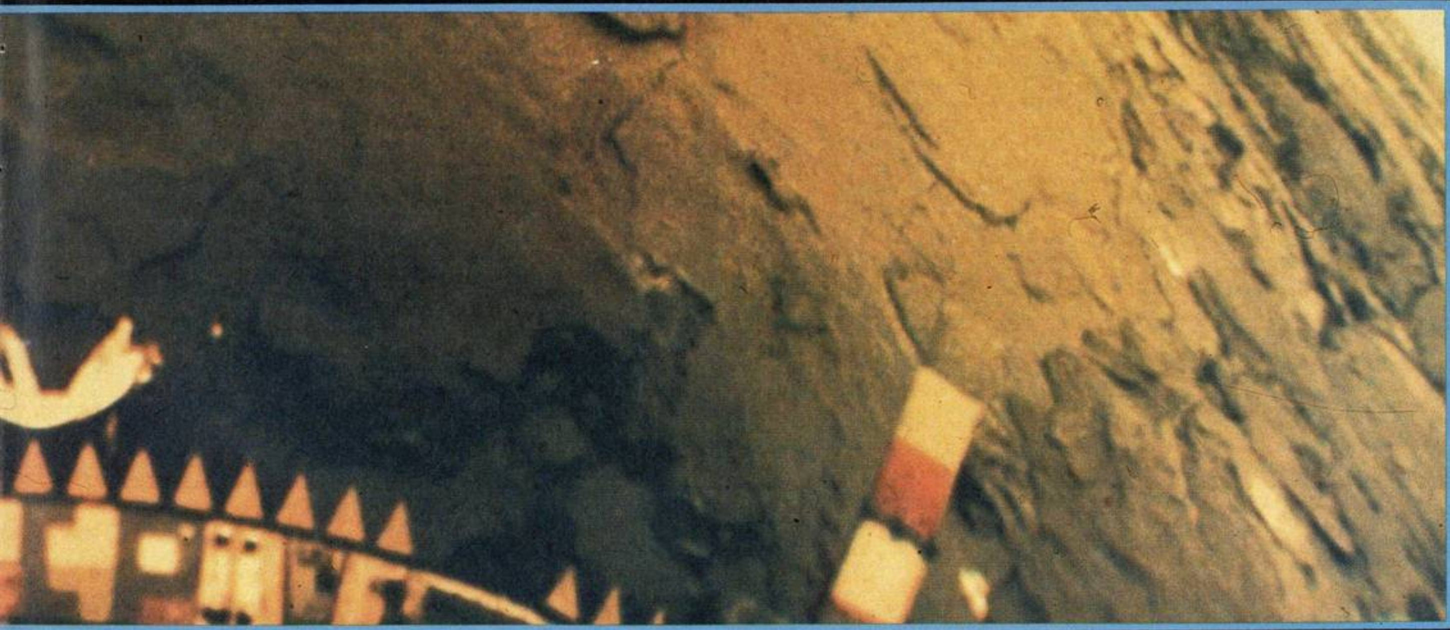
The ground at the site is typically light colored, but different layers show varying hues — indicating that each has a somewhat different composition. The layering is well defined, with at least six different levels visible in one particular place. These sheets of rock are apparently very old and are made up of fine materials. The horizon line is even and distinct in the photos. No dust cloud billowed up during the landing at this site.

Everything on Venus is orange! The venusian atmosphere selectively filters out the blue wavelengths and illuminates the entire surface with orange-green light. The ground is yellow-orange. The sky is orange. The clouds are orange.

Perhaps even more intriguing than the photographs were the hard data on the composition of the surface. Each lander had a soil analysis experiment mounted on a shock-absorbent ring that encircled the main spherical body of the lander. The landers obtained one sample from each site by drilling 30 millimeters into the surface soil with sophisticated mechanisms capable of operating under the extreme venusian conditions.

After the samples were collected, they were passed from the outside of the lander into insulated airtight spheres that housed the crafts' delicate instruments. Then — in a controlled environment free from contaminants — the samples were stimulated with radioactive plutonium and iron sources and studied by X-ray fluorescence spectrometers. Forty excellent spectra were obtained by Venera 13, and 20 more by its sister craft.





Venera 14's spiky outline, camera hatch, and color gauge superimpose human technology on the venusian landscape near Beta Regio. Tass from Sovfoto.

The data are preliminary, but Barsukov described the rocks as similar in composition to terrestrial oceanic basalts — though they do not appear to be volcanic as terrestrial basalts are. The compositions of the soil at the two sites are slightly different. Rocks at the Venera 14 site showed a lower potassium content than their counterparts near Venera 13. In general, the rolling uplands of the Phoebe Regio site are similar to the terrestrial crust, and they are probably remnants of the ancient venusian crust. The lowlands near Beta Regio are much younger. It appears that Venus evolved in a completely different fashion than the Earth and Moon.

Veneras 13 and 14 sampled the atmosphere during their descent using new instruments specifically designed for the mission. A mass spectrometer some 20 times more sensitive than those on the earlier Venera craft measured isotopes of argon, neon, krypton, and xenon in the atmosphere. A gas chromatograph and an electron detector searched for oxygen and sulfur compounds. A hydrometer — a new instrument designed to measure the water content of a gas by sending electrical currents through it — found that water made up about 0.001 percent of Venus' lower cloud layer composition. This instrument was sensitive to a change in water content as small as 0.00001 percent!

The landers also studied the venusian clouds from 60 kilometers down to 42 kilometers above the surface and revealed that they are made up predominantly of micron-size spherical drops and crystals of yet unknown composition. The Venera 12 mission detected chlorine in the clouds, and Venera 14 determined that sulfur was present in quantities only a tenth as great as the chlorine. Wind velocity data were not yet available, though earlier missions showed velocities as high as 200 m/sec in the upper atmosphere, and as low as 1 to 2 m/sec at the surface. Much of the analysis was still being interpreted the week of the

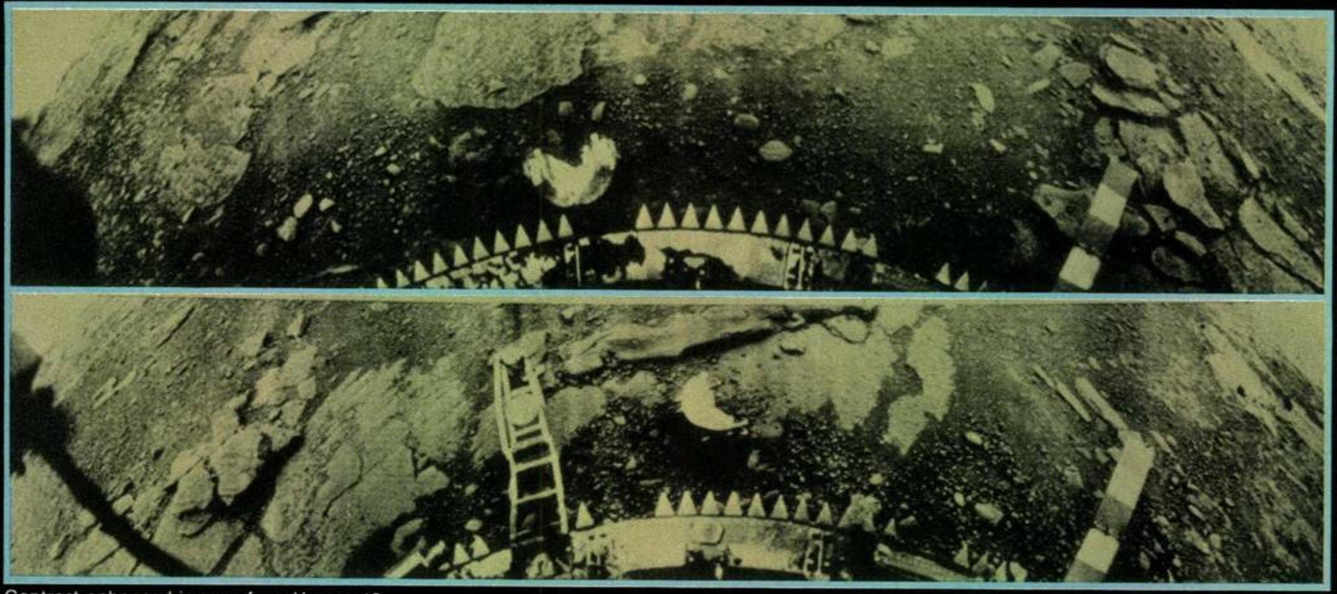


Photo courtesy of NASA

Contrast-enhanced images from Venera 13

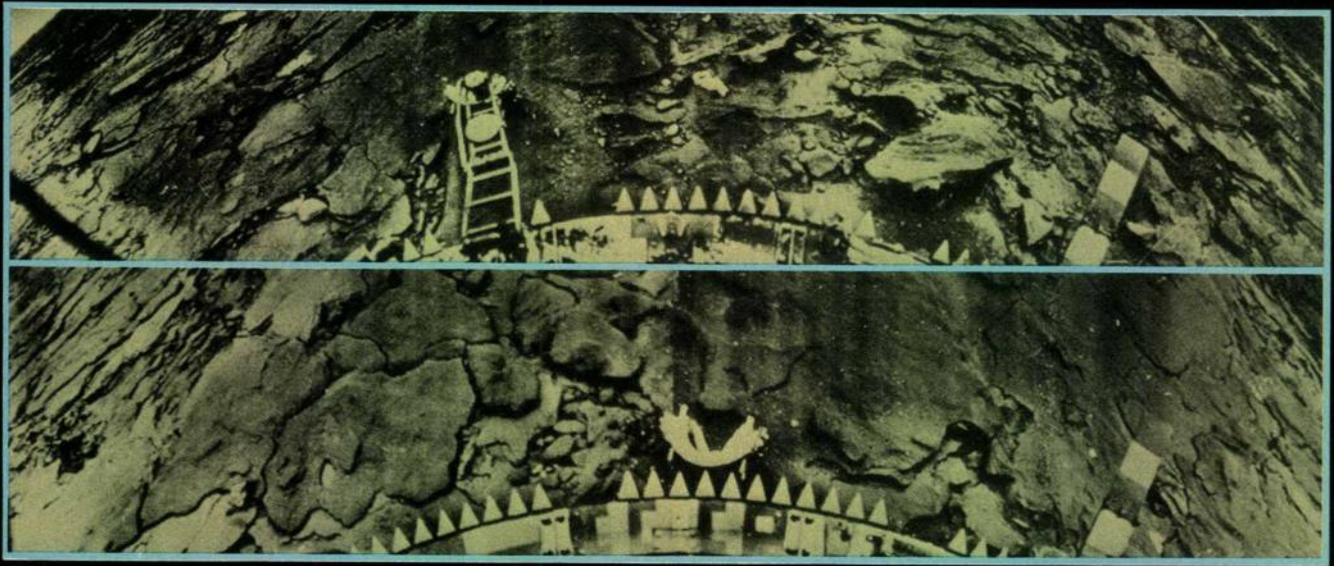


Photo courtesy of NASA

Contrast-enhanced images from Venera 14

Soil Compositions Measured by Venera Probes

Mineral	**Venera 13**	**Venera 14**
Periclase (MgO)	10% ± 6	8% ± 4
Corundum (Al_2O_3)	16 ± 4	18 ± 4
Quartz (SiO_2)	45 ± 3	49 ± 4
Potassium oxide (K_2O)	4 ± 0.8	0.2 ± 0.1
Calcium oxide (CaO)	7 ± 1.5	10 ± 1.5
Rutile (TiO_2)	1.5 ± 0.6	1.2 ± 0.4
Manganese oxide (MnO)	0.2 ± 0.1	0.16 ± 0.08
Ferrous oxide (FeO)	9 ± 3	9 ± 2

landings, but Barsukov promised that more atmospheric data would be available soon. He even told of putting some of the data together on the plane on his way to the conference!

The Soviets are by no means through with Venus; they already have intensive new missions in the works — including an international project between Eastern Bloc countries — to send two more landers to the venusian surface. As a bonus, a third craft would slingshot around the planet to rendezvous with Halley's Comet on March 8, 1986. And Venus is not the only focus of Soviet planetary exploration; they plan to return samples from both the near and far sides of the Moon. The Soviet program was well summarized by Mike Duke of Johnson Space Center when he said: "This mission shows what can be accomplished by a steady commitment to the space program." Maybe someone in Washington was listening.

Barsukov closed his talk with this optimistic comment: "Now that we know none of the other planets in our solar system is habitable, we should strive for peace and true cooperation on our world." And just to start things rolling in the right direction, he presented a complete set of photographs from the missions to Duke, and another to Harold Masursky, who worked closely with the Russians in selecting landing sites from NASA radar data.

The several hundred scientists in the room that Wednesday afternoon will not forget the excitement and genuine scientific cooperation brought about by the Venera landings. If this spirit were dissolved by mere political differences, all of us would suffer a devastating loss.

Sam Mims is the curator of the Louisiana Arts & Science Center Planetarium in Baton Rouge. He publishes Space News, *a newspaper for astronomy enthusiasts, and edits the* Journal of Meteor Research.

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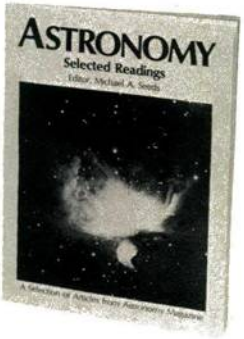

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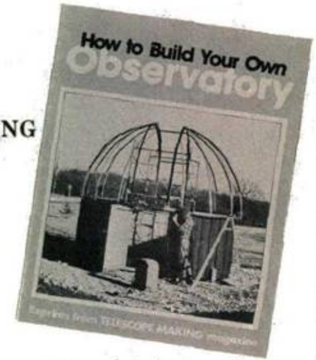

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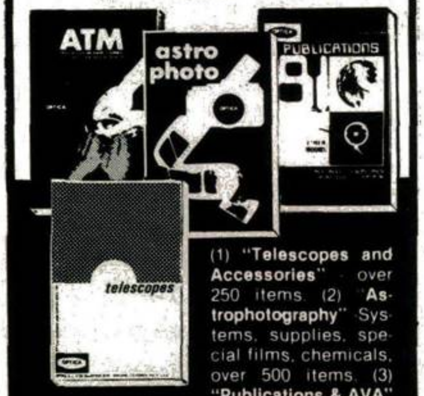

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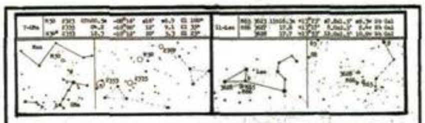

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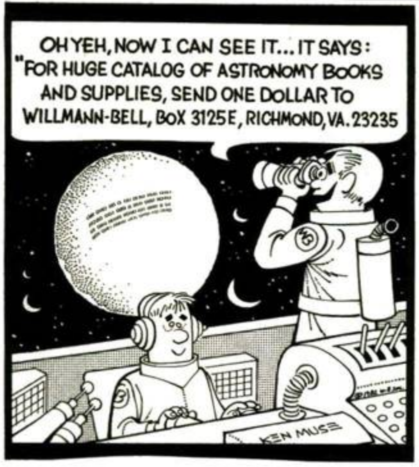
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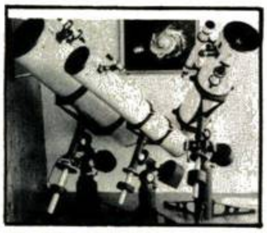

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the backyard astronomer

sagittarius

Mercury

Mercury will be visible before sunrise low in the east-northeastern sky until shortly after mid-July. Then the small planet moves too close to the Sun, and will not be seen again until late August when it begins its worst apparition for the entire year.

During July, Mercury's disk stays small: 7.2" on the first will dwindle to 5.3" by the 18th. In this same period, its phase — half-lit on the first — will round out to 94% lit. On the 25th, it will pass through superior conjunction.

Venus

Though it drops slightly lower over the course of the month, Venus will still hold most of its elevation during July. The planet will be about 1.4 AUs distant on the 15th, with a disk 87% illuminated and 11.9" of arc across.

On the 18th, the nearly New Moon will occult Venus, but the event is visible only from the South Pacific and New Zealand.

Earth

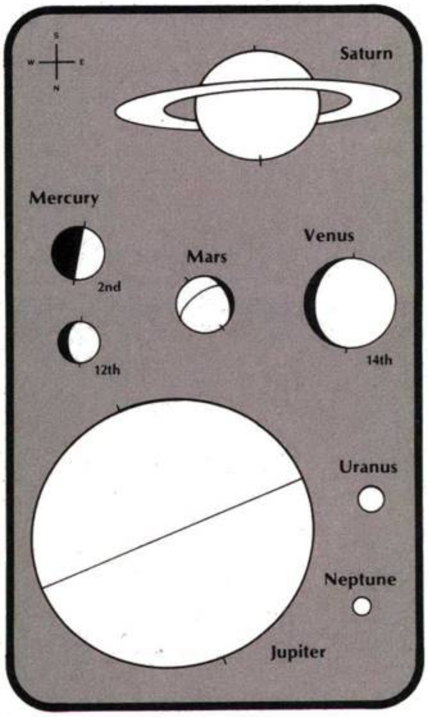
On July 4, at 13h UT, Earth passes the aphelion of its orbit. At that time, we will be 1.0166836 AUs, or 152,093,701 km, from our luminary, the Sun. At aphelion, sunlight has only 94% of the strength it has at perihelion in January.

Aphelion during the northern hemisphere's summer is particularly fortunate. The great land masses of the northern hemisphere respond rapidly to changes in solar radiation and, without the summer-aphelion coincidence, the seasons would swing wildly between severe summers and winters. The southern hemisphere, with its winter at aphelion and summer at perihelion, doesn't suffer these great seasonal temperature changes because it has few large land masses and an abundance of ocean water that responds slowly to changes in solar radiation.

One of the many glories of the summer Milky Way is the Trifid Nebula, M-20, in Sagittarius. The bluish part is dust that reflects the light of a hot star; the red glow indicates ionized hydrogen gas. John Gleason used 400 ASA film and a 45-minute exposure at f/11 with a 14-inch Schmidt-Cassegrain telescope.

Moon

The big event this month involving the Moon is the total lunar eclipse early on July 6. See Gazer's Gazette starting on page 47 for full details.



We'll also see another July eclipse. Two weeks after the lunar eclipse, on July 20, the Moon, passing through New, will obscure (at maximum) 46% of the solar disk. The regions favored by this partial solar eclipse are the north pole, Iceland, Greenland, the Canadian Arctic, northern Alaska, northeastern Siberia, the arctic coastline of the Soviet Union, Norway, Sweden, and the rest of Western Europe as far south as the middle of Spain.

Mars

Anyone who has followed the motions of Mars since May has seen the planet move briskly eastward along the ecliptic. This path is taking Mars toward more southerly declinations and will steadily make it more difficult to observe. Very late on the 9th (23:40 UT), the Red Planet passes about 3° south of Saturn, and on the 21st, a degree and a half north of Spica.

Through even a small telescope, Mars' disk shows a strong phase effect because we are viewing the planet about 42° away from the direction of illumination from the Sun.

At present, the martian season is late summer for the northern hemisphere; the autumnal equinox will come during the last week of August. In mid-July, Earth lies directly over the martian 23° north parallel.

Asteroids

1 Ceres (magnitude 7.9) lies in western Libra. Its positions:

10th: 14h 46m 27s, –11° 41′ 12″
20th: 14h 49m 25s, –12° 37′ 54″

Ceres sets around 1 a.m. local daylight time in the middle of the month.

2 Pallas (9.4) is in Coma Berenices, near its border with Virgo. Its positions:

10th: 13h 14m 34s, +19° 21′ 58″
20th: 13h 24m 00s, +18° 06′ 55″

Pallas sets around 1 a.m. local daylight time in mid-July.

3 Juno (10.1) is retrograding in eastern Ophiuchus. Its positions:

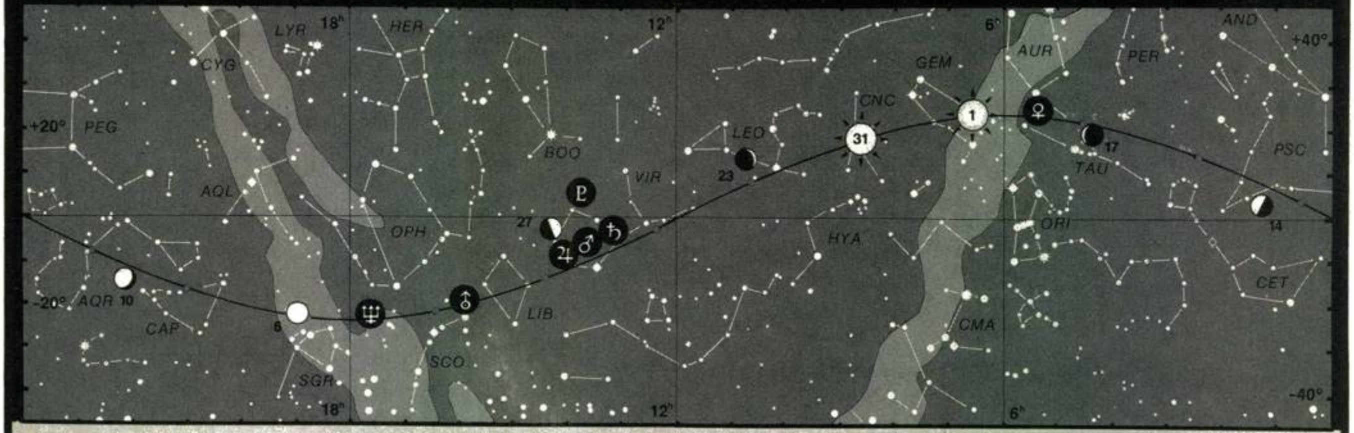
10th: 17h 53m 53s, –5° 13′ 50″
20th: 17h 46m 13s, –5° 45′ 21″

Juno sets around 4:30 a.m. local daylight time on July 15.

4 Vesta (6.1) lies in eastern Capricornus. Its positions:

10th: 21h 49m 36s, –18° 23′ 43″
20th: 21h 44m 57s, –19° 38′ 41″

planetary data july 1982


18h
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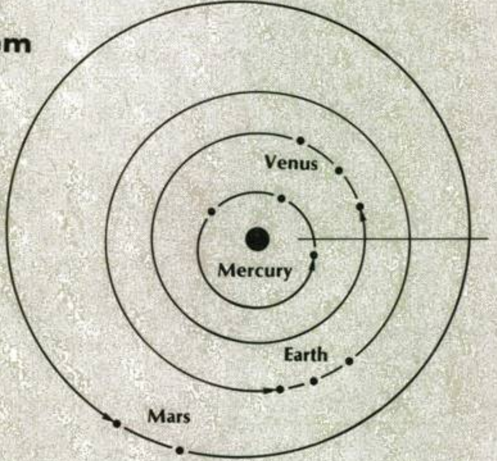
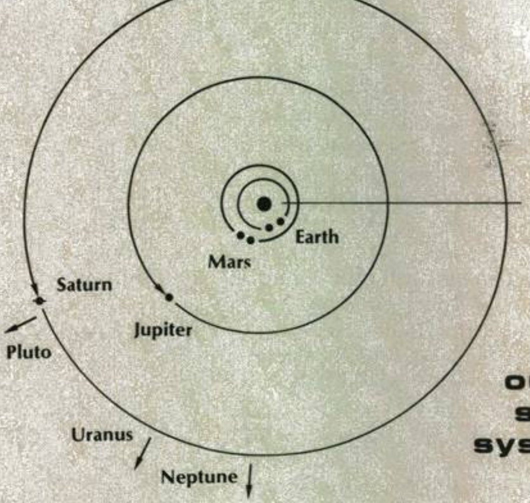
-40°

inner solar system


Venus
Mercury
Earth
Mars


Earth
Mars
Saturn
Jupiter
Pluto
Uranus
Neptune

outer solar system

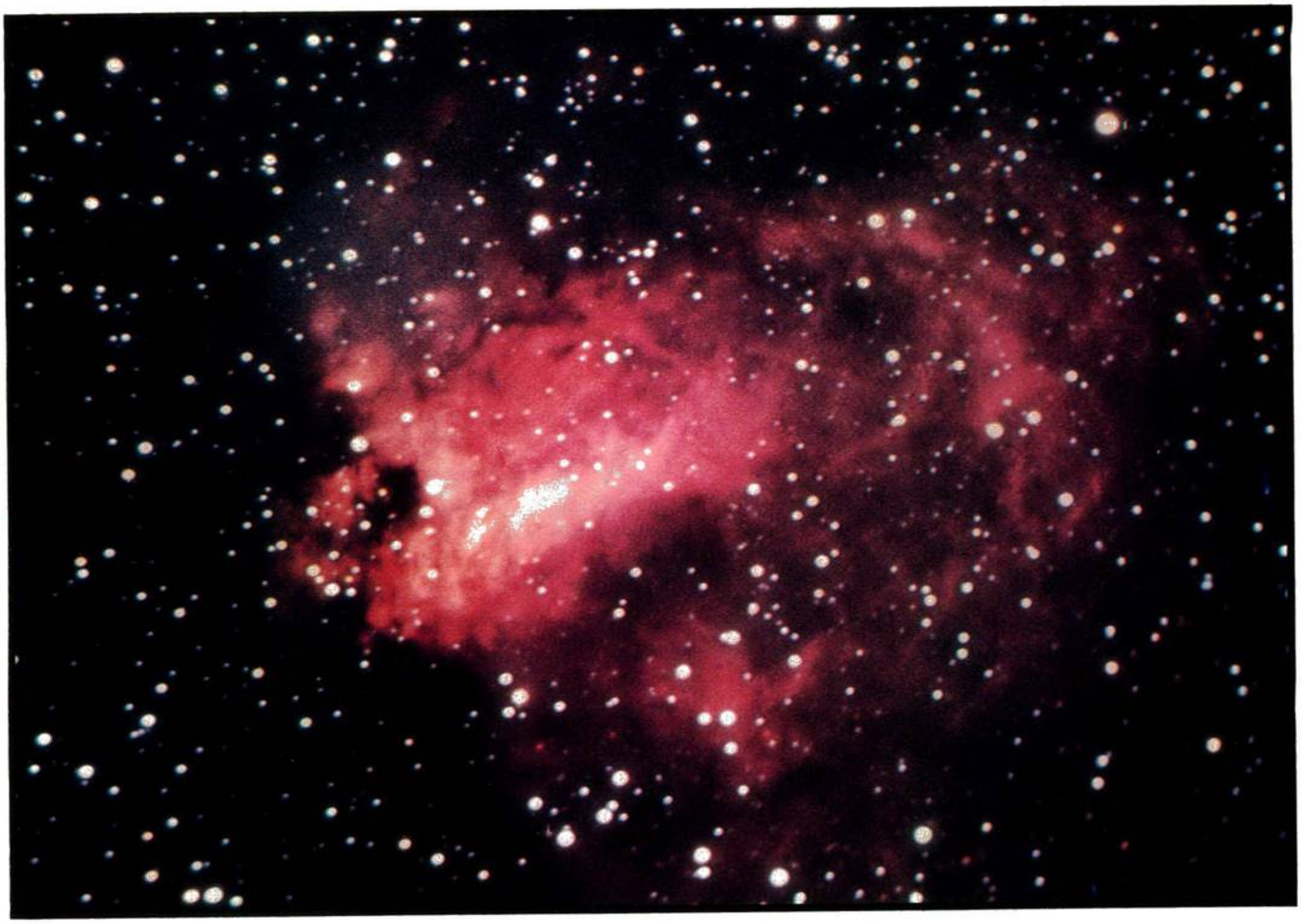
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1982.6)	Dec
Sun		1	−26.7	31.5′	—	1.02	—	—	98°51.5′	6h 38.5m	+23°08.7′
		15	−26.7	31.5′	—	1.02	—	—	112°12.2′	7h 35.9m	+21°36.8′
		31	−26.7	31.6′	—	1.02	—	—	127°29.1′	8h 39.5m	+18°24.2′
Mercury	☿	1	+0.3	7.2″	48%	0.93	0.37	344°15.0′	77°03.7′	5h 06.2m	+20°18.6′
		15	−1.1	5.5″	87%	1.22	0.31	58°13.7′	99°54.8′	6h 45.2m	+23°20.8′
		31	−1.3	5.0″	92%	1.34	0.35	152°14.9′	133°14.8′	9h 06.9m	+18°24.5′
Venus	♀	10	−3.4	12.1″	85%	1.39	0.72	32°12.9′	76°46.1′	5h 04.9m	+21°35.7′
		31	−3.3	11.2″	90%	1.50	0.72	65°53.7′	101°59.9′	6h 53.9m	+22°33.5′
Mars	♂	15	+0.6	7.9″	87%	1.18	1.52	241°25.4′	199°08.6′	13h 11.4m	−8°06.2′
Jupiter	♃	15	−1.7	38.0″	99%	5.18	5.42	223°55.8′	210°27.8′	13h 56.7m	−10°41.0′
Saturn	♄	15	+1.0	17.1″	100%	9.75	9.70	203°04.8′	195°38.9′	13h 03.1m	−4°02.6′
Uranus	♅	15	+5.9	3.7″	100%	18.24	18.89	243°15.3′	240°27.6′	15h 54.9m	−20°10.9′
Neptune	♆	15	+7.7	2.5″	100%	29.36	30.27	265°50.2′	264°31.9′	17h 38.2m	−22°02.2′
Pluto	♇	15	+13.8	—	100%	29.90	29.95	206°11.3′	203°44.8′	13h 54.4m	+6°32.0′

moon data

Full Moon	July 6 at 7:32
Last Quarter	July 14 at 3:47
New Moon	July 20 at 18:57
First Quarter	July 27 at 18:22
Full Moon	August 4 at 22:34
Last Quarter	August 12 at 11:08
Apogee: July 5 at 1h	406,161 km
Perigee: July 19 at 21h	358,802 km

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then EDT for the event is 11 p.m., June 6. Likewise, 03:00 UT on September 2 becomes, in PDT, 8 p.m., September 1.



Another luminous cloud of hydrogen gas in Sagittarius is the Omega Nebula, M-17. Ben Mayer took its portrait with a 90-minute exposure on 200 ASA film in a cold camera at f/11 with a 14-inch Schmidt-Cassegrain telescope. He re-photographed the slide to increase contrast and reveal faint nebulosity.

Vesta rises about 10:30 p.m. local daylight time on July 15.

All asteroid positions are in 1950 coordinates.

Jupiter

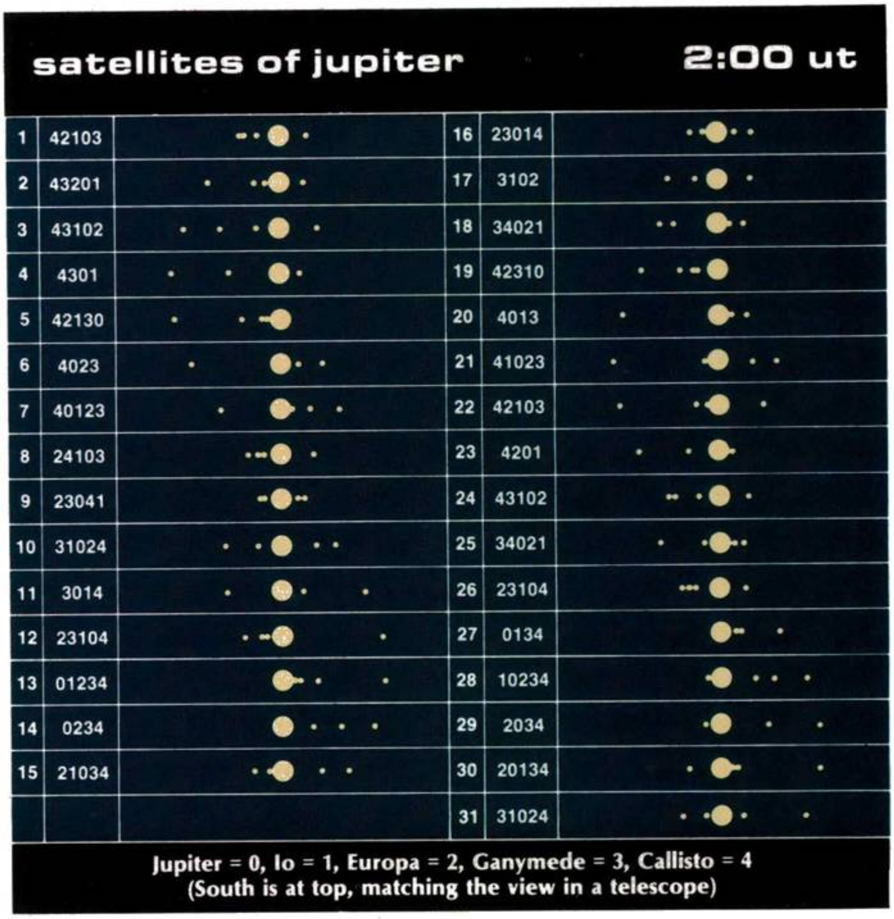
As with Mars, we also see a phase effect with Jupiter this month. But we are only about 11° off the Sun-Jupiter line, compared to 42° with Mars, so the effect is less pronounced. You'll see it best in medium and large-size instruments. The effect is probably enhanced by the layers of cloud that make up the "surface" of Jupiter; they reflect light back to us less efficiently when they lie along the limb of the planet than when they are central on the disk.

Saturn

By now, the part of the sky where Saturn lies is setting earlier. The end of the saturnian observing season is in sight, though the planet will be visible for about two more months.

Uranus

During July, Uranus is coasting



satellites of jupiter **2:00 ut**

1	42103	16	23014
2	43201	17	3102
3	43102	18	34021
4	4301	19	42310
5	42130	20	4013
6	4023	21	41023
7	40123	22	42103
8	24103	23	4201
9	23041	24	43102
10	31024	25	34021
11	3014	26	23104
12	23104	27	0134
13	01234	28	10234
14	0234	29	2034
15	21034	30	20134
		31	31024

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

This photograph of a thin crescent Moon wins the "Best Astro-Photo" award for July. Russell Beatty deliberately overexposed the sunlit crescent and used a 45-second exposure on 400 ASA film to reveal the part of the Moon illuminated by sunlight reflected from Earth. He used an 8-inch f/10 Schmidt-Cassegrain.

leisurely westward on the Scorpius-Libra border toward its stationary point, which it will reach on August 9. The star closest to it is 5th magnitude Lambda (λ) Librae. Uranus lies just 2 or 3 minutes of R.A. east and only a few more minutes of arc south of the star. Uranus has a disk 3.8" of arc across and is at 5.8 magnitude.

Neptune

Neptune lies about a degree north of the ecliptic in southern Ophiuchus. You can locate it most easily by hopping from 4.9 magnitude 58 Ophiuchi. Neptune is moving slowly westward about 20′ of arc south of the star; it lies about 2 minutes of R.A. west of it at the beginning of July and about 6m west by the end of the month.

Meteors

Two relatively prominent annual showers reach peak activity in July: the Delta Aquarids (which have two separate streams) and the Capricornids. Both happen late in the month when the Moon is just past First Quarter and will not interfere.

The Delta Aquarids have no pronounced peak date. You can see the two streams — the north and south Delta Aquarids — anytime between mid-July and the end of August. This year's display will probably be strongest around the 28th or 29th.

Delta Aquarid meteors are usually bright, yellowish, and not very fast. The hourly rate for a single observer under dark skies is around 20 meteors. Determining what meteor belongs to which of the two streams (or to the Capricornids) is practical only with photography. The radiants lie close together and each is fairly diffuse.

On the 30th — one or two days after the Delta Aquarid peak — the Capricornids reach their maximum activity. Less plentiful, with an hourly rate around 10, they are also yellow and slow — but they produce a good number of fireballs.

close-up on sagittarius

When you aim your scope below the star Gamma Sagittarii at the **Great Sagittarius Star Cloud**, you peer through 33,000 light-years of space toward the galactic center — around which the rest of the Milky Way revolves. Although the actual nucleus is obscured by the incredible clutter of stars and dust you see there, astronomers believe that the Sagittarius Cloud is a portion of the central hub. But central hub or not, the array of clusters and nebulae offered by this stellar concentration can keep you busy all summer long.

The largest bright patch in this area is M-8, the **Lagoon Nebula**. It lies 5° west of Lambda Sagittarii in the handle of the "Milk Dipper," on the edge of the Milky Way itself. M-8 is easily visible to the naked eye, and in the eyepiece, it seems to envelop the open cluster, **NGC-6530**.

Through small apertures you'll probably see only the cluster — unless the night is very dark. But in rich field telescopes or scopes with large aperture you'll be able to glimpse the glowing nebulosity as easily as you can when viewing M-42. M-8's proximity to the horizon also adds to its low contrast. Try averted vision if you think you see it but aren't sure.

T.W. Webb described the Lagoon as a "splendid galaxy object; visible to the naked eye. In a large field we find a bright coarse triple star, followed by a resolvable luminous mass, including two stars, or starry centers, and then by a loose and bright cluster enclosed by several stars: a very fine combination." C.E Barns called it a "naked eye wonder, resembling somewhat the Pleiades, involved in wide wastes of incandescent hydrogen and helium, overflung with dark, absorbing patches."

The wide expanse of M-8 is hard to fit into most fields of view, so use your lowest power, widest field eyepiece. Sometimes binoculars will give a better view. The eastern half of the nebula contains the loose open cluster NGC-6530, about 10′ of arc in diameter.

The area immediately surrounding the nebula is a good place to aim a large telescope. One degree southeast is the faint and distant globular, **NGC-6544**; move your scope another degree to the southeast and a second globular — **NGC-6553** — will pop into view. One and-a-half degrees to the east-northeast of M-8 are two nebulous bits, **NGC-6559** and **IC 4681**.

Swing your scope around to the northern border of Sagittarius/Scutum and you'll find **M-17**, the Omega, Swan, or Horseshoe Nebula. M-17 was discovered in the spring of 1764 by the Swiss astronomer de Cheseaux who referred to it as "a nebula which has never been discovered; it has a shape quite different from the others; it has the perfect form of a ray or the tail of a comet, 7′ long and 2′ wide. Its sides are exactly parallel and well terminated." Messier saw M-17 a few weeks later as "a train of light without stars, in the shape of a spindle, a little like that in Andromeda's belt."

For the modern observer, the most

Sweeping your telescope through southern Serpens near its border with Scutum will reveal the dust-obscured glow of the Eagle Nebula, M-16. John Gleason used a 45-minute exposure at f/11 on 400 ASA film with his 14-inch Schmidt-Cassegrain telescope to capture both the nebula and nearby stars.

striking feature in M-17 is the long, bright, comet-like streak across its northern edge. On the west end a curved hook gives the whole nebula a resemblance to a ghostly figure "2" with the bright streak forming the base. It doesn't take much imagination to conjure up the shape of a swan, the Greek letter omega, or a horseshoe out of this nebulosity.

Just one degree south of M-17 and slightly west is the small open cluster **M-18**, not one of the finest showpieces in Sagittarius, but worth a glance. Messier described it as a "cluster of small stars a little below M-17, surrounded by a slight nebulosity." The whole object is little more than a grouping of a dozen small stars, but it is fairly easy to find because, unlike many clusters in Sagittarius, it shines against a dark background.

Dropping back down toward the concentration of the Sagittarius Star Cloud, you'll find a smaller patch of luminosity just above the Lagoon — M-20, the **Trifid Nebula**. John Herschel named the object and described it as "three bright and irregularly formed nebulous masses, graduating away insensibly externally, but coming up to a great intensity of light at their interior edges where they enclose and surround a sort of three forked rift or vacant area, abruptly and uncouthly crooked and quite void of nebulous light... a beautiful triple star is situated precisely on the edge of one of these nebulous masses just where the interior vacancy forks into two channels."

In eight to ten-inch scopes, M-20's triple-nature is easy to detect and stands out as one of the more amazing sights in the heavens. Even if you view it through a small telescope, you'll be impressed at the wealth of detail visible in this region. Although the Great Trifid Nebula won't look like those long-exposure observatory photographs, it is one of the brighter celestial objects, and will always be a pleasing eyepiece sight.

In the same low-power field with the Trifid is the small, compact star cluster, **M-21**. The cluster is highlighted by six 8th magnitude stars in a tight knot, and surrounded by several dozen scattered members.

Ranking third in magnitude among all globulars is **M-22**, the "Great Globular," 2.3° northeast of Lambda in Sagittarius. Early astronomers observed the object, but William Herschel was the first to turn a large telescope toward it and determine its true nature. He found it to be a "magnificent globular star cluster, gradually brighter in the middle, but not to a nucleus."

The Great Globular is easy to resolve; its brightest stars are 11th magnitude, and hundreds of its member stars are within the range of an 8-inch scope. The stellar population of the cluster is more than a half a million; about 75,000 star images showed on a plate taken by John Duncan with the Mt. Wilson 60-inch!

M-22 is also one of the closest globulars to our solar system, and no doubt the closest globular you can see from the northern hemisphere — only 9600 light-years away. About a degree to the west-northwest is the small faint cluster **NGC-6642**, looking like a fuzzy ball just one minute of arc in diameter — obviously a much more distant and smaller globular than M-22.

Another attractive object for small telescopes is **M-23**, a widely spaced galactic cluster of about 100 stars. It lies about 5° northwest of Mu Sagittarii in a fairly sparse field. C.E. Barns described it as "a blazing wilderness of starry jewels." Burnham said he got his best look at it through a 10-inch f/6 reflector at 45x; it filled the field from edge to edge with just enough dark sky for good contrast.

Instead of taking out a book tonight and targeting the objects listed, scan the heavens at random, allowing your scope to rest where it will. Some object is sure to be in the field in this densest of all Milky Way regions.

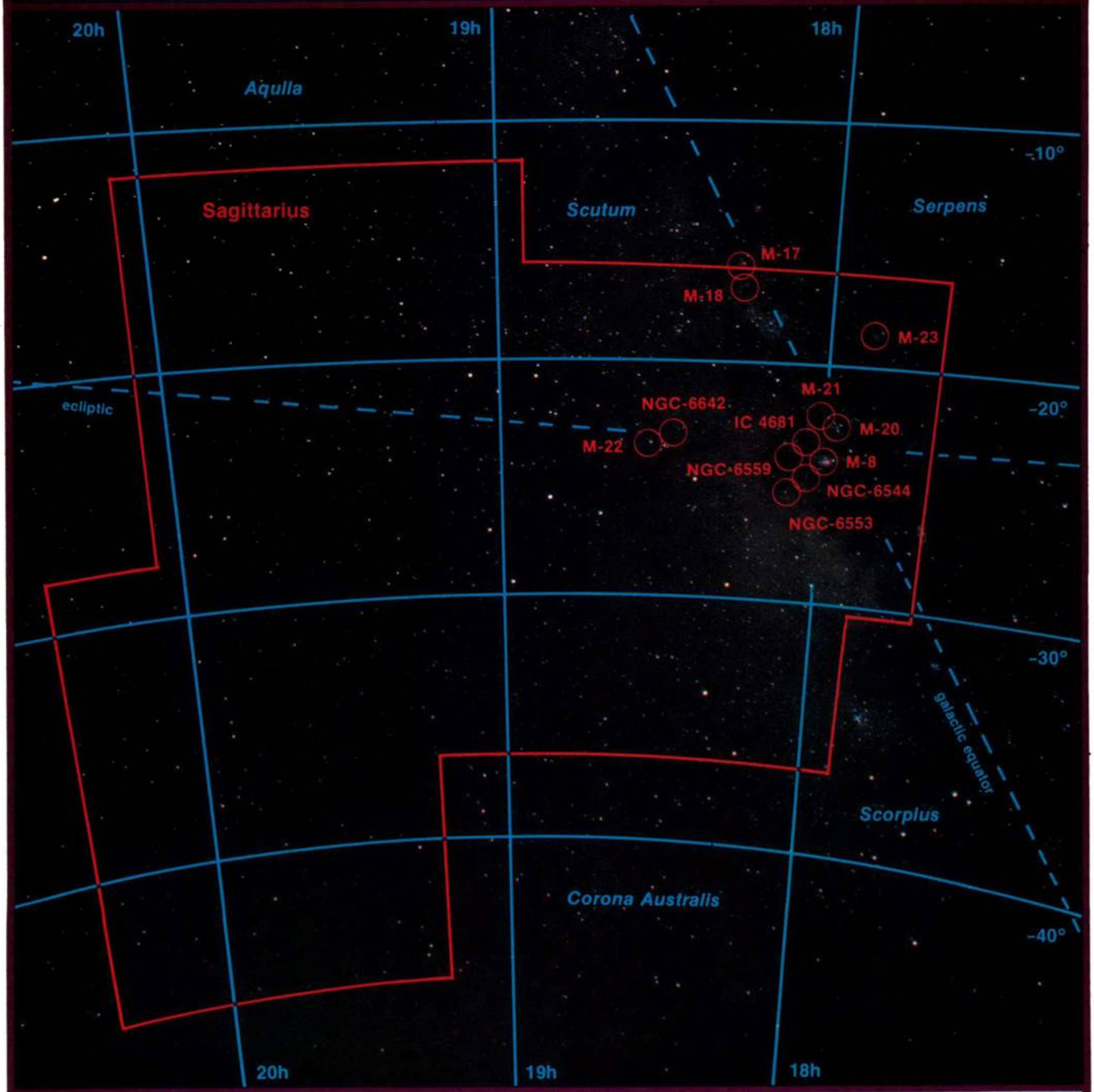
In these days of computer-driven pointing devices, we should try to preserve the romance of the hunt. The ancient Chinese sage Lao Tzu said it this way 2,500 years ago:

"He who walks in harmony with the eternal Way shall be the master of existence; knowing the ancient beginning is the essence of enlightenment. This is the mystic unity of the Way."

sagittarius

photo by Brad Wallis and Robert Provin

map by Robert Burnham


20h
19h
18h
Aquila
-10°
Sagittarius
Scutum
Serpens
M-17
M-18
M-23
M-21
ecliptic
NGC-6642
IC 4681
M-20
-20°
M-22
NGC-6559
M-8
NGC-6544
NGC-6553
-30°
galactic equator
Scorpius
Corona Australis
-40°
20h
19h
18h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
M-23	○	6.9	25′	17h54m	-19°01′	17h58m	-19°01′
M-20 (Trifid)	□	6	30′	17h59m	-23°02′	18h02m	-23°02′
M-8 (Lagoon)	□	5	60′x35′	18h02m	-24°20′	18h05m	-24°20′
NGC-6530	○	6.3	10′	18h02m	-24°20′	18h05m	-24°20′
M-21	○	6.7	12′	18h02m	-22°30′	18h05m	-22°30′
NGC-6544	●	9	1′	18h04m	-25°01′	18h07m	-25°01′
IC 4681	□	9	8′	18h05m	-23°27′	18h08m	-23°27′
NGC-6553	●	10	2′	18h06m	-25°56′	18h09m	-25°55′
NGC-6559	□	10	8′x5′	18h07m	-24°08′	18h10m	-24°07′
M-18	○	7.5	12′	18h17m	-17°09′	18h20m	-17°08′
M-17 (Omega)	□	7	7′x2′	18h18m	-16°12′	18h21m	-16°11′
NGC-6642	●	8	1′	18h29m	-23°31′	18h32m	-23°29′
M-22	●	5.9	18′	18h33m	-23°58′	18h36m	-23°55′

★	*Star*
★²	*Double Star*
★³	*Triple Star*
m★	*Regular Variable*
n★	*Irregular Variable*
✕★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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